TP 4993E

FINAL REPORT

INSTALLATION COMMISSIONING AND TESTING OF DOPPLER RADIO DIRECTION FINDER

PROJECT 4711:
DSS FILE 11SD.T8200-9-9530/1
TDC FILE D1455-133-4

Prepared for : TRANSPORTATION
DEVELOPMENT CENTRE
1000 Sherbrooke Street West
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October 1983

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FINAL REPORT

INSTALLATION, COMMISSIONING AND TESTING OF DOPPLER RADIO DIRECTION FINDER

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by:

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167 Hunt Street, Ajax, Ontario

October 1983

The contents of this report reflect the views of the contractor and not necessarily the official views or policies of the Transportation Development Centre.

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17. Abstract

The report covers the Installation, Commissioning and Testing of Doppler Radio Direction Finder Equipment.

The equipment was installed at Norman Rogers Airport, Kingston, Ontario. The equipment was demonstrated to Transport Canada in September 1982 and March 1983. The September 1982 results did not achieve the predicted field performance of the system. Corrective action was initiated and a second demonstration to Transport Canada was made in March 1983. At certain azimuth angles, the errors were in excess of the specified limits. The problem has been traced to the discontinuity of phase detector characteristics at $\pm 180^{o}$. The circuit has been modified and tests have been repeated. The final test results indicate that the equipment could satisfy the performance requirement.

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17. Résumé

Ce rapport concerne l'installation, la mise en service et l'essai d'un radiogoniomètre Doppler.

L'appareil a été installé à l'aéroport Norman Rogers à Kingston (Ontario) et des démonstrations faites devant Transports Canada en septembre 1982 et mars 1983. La première n'a pas donné les résultats souhaités. Après les rectifications nécessaires, une deuxième démonstration a été faite en mars 1983 (Annexe II). Il a été constaté que, à certains angles d'azimut, les erreurs de gisement étaient supérieures aux valeurs prescrites. La raison invoquée est la discontinuité dans la détection de phases qui apparaît à ±180° d'angle. Les circuits ont été modifiés et, à la reprise des essais, il a pu être constaté que l'appareil donnait satisfaction.

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SUMMARY

This report covers installation, commissioning and testing of a Doppler radio direction finder, performed by Bayly Engineering Limited, under DSS Contract No. 11SD.T8200-9-9530/1.

The project was an extension to the development contract of a VHF Doppler Direction Finder under DSS Contract No. 09SD.T8200-9-9530 and described in Transport Canada Report No. TP3866E.

The program was initiated with the intention to evaluate the performance of the equipment in the field, and also to demonstrate to the prospective user the features of the system, and to solicit the operator's comments. The equipment was installed at Norman Rogers Airport, Kingston, Ontario and, after system alignment and preliminary tests by company personnel, the equipment was demonstrated to Transport Canada, Telecommunications and Electronics - Air, in September 1982 and March 1983. The September 1982 results did not achieve the expected results. Corrective action was instituted and equipment modified and a second demonstration to Transport Canada was arranged in March 1983. At this time, two areas came to light:

i) at certain azimuth angles, the bearing errors were in excess of 6° due to phase detector discontinuity near ±180°, and

ii) the maintenance of the equipment under service conditions was unacceptable to the end user, due to the antenna unit being located at the top of the antenna mast.

The phase detector discontinuity was corrected by modifying the circuit and tests repeated showing that the equipment could meet the electrical performance requirement. However, the maintenance problem required major equipment repackaging and this work is being done under a separate contract and will be reported later.

The test results covered in this report are given in Appendix 1 (September 1982) and Appendix 2 (March 1983) together with a supplement on phase detector ambiguity.

For completeness of the report, the System Field Performance Test Procedures are attached herewith in Appendix 3 (September 1982 tests) and Appendix 4 (March 1983 tests) respectively.

SOMMAIRE

Le présent rapport concerne l'installation, la mise en service et l'essai d'un radiogoniomètre Doppler, travaux entrepris par Bayly Engineering Limited aux termes du marché MAS n° 11SD.T8200-9-9530/1.

Le projet en question est le prolongement de l'étude d'un radiogoniomètre VHF, conduite en vertu du marché MAS n° 09SD.T8200-9-9530 et décrite dans le rapport n° TP3866E de Transports Canada.

Ce programme a été lancé dans le but d'évaluer les performances in situ de cet appareil et aussi pour montrer à l'utilisateur les caractéristiques du système et obtenir de l'opérateur des commentaires pertinents. L'appareil a été installé à l'aéroport Norman Rogers à Kingston (Ontario). Apprès la mise au point et les essais préliminaires nécessaires, effectués par la compagni Bayly, deux démonstrations ont été faites en présence de Télécommunications et électronique - Air, de Transports Canada, l'une en septembre 1982 et l'autre en mars 1983. La premiére n'a pas donné les résultats souhaités; mais, apres rectification et modification de l'appareil, la seconde, a permis de faire les constatations suivantes:

i) à certains angles d'azimut, les erreurs de gisement dépassaient 6°, dues à une discontinuité dans la détection des phases a ±180° d'angle;

ii) l'entretien de l'appareil en service était difficile parce que l'antenne se trouvait au sommet du mât d'antenne.

La discontinuité dans la détection des phases a pu être corrigée en modifiant les circuits et, à la reprise des essais, il a été constaté que l'appareil donnait satisfaction du point de vue électrique. Quant aux problemes d'entretien, ils nécessitent la réétude en profondeur de la configuration de l'appareil, ce qui se fait aux termes d'un marché séparé dont il sera rendu compte ultérieurement

Le résultat des essais décrits dans le rapport apparaît a l'annexe I (Essais de septembre 1982) et à l'annexe II (Essais de mars 1983), auxquelles s'ajoute un supplément sur la question de l'ambiguité dans la détection des phases.

Le tout est complété par les annexes III et IV détaillant le mode opératoire des essais effectués in situ en septembre 1982 et mars 1983, respectivement.

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APPENDIX 4	SYSTEM FIELD PERFORMANCE TEST PROCEDURE March 1983

1. INTRODUCTION

The Quasi-Doppler VHF Radio Direction Finder was developed by Bayly Engineering Ltd. under the sponsorship of Transport Canada, Transportation Development Centre, Montreal, Quebec. The first prototype equipment was assembled and tested in the Granby plant of the Company in January 1982. At this point, following a review meeting, permission was granted by Transport Canada to transfer the equipment to Norman Rogers Airport in Kingston, where arrangements were made to have it installed for an operational field evaluation.

The present contract covers the tasks of installation, commissioning and testing of the prototype equipment, including any work necessary to put it in operation to the satisfaction of Transport Canada representatives.

2. PERFORMANCE OF CONTRACTUAL ASSIGNMENTS

2.1 Installation at Norman Rogers Airport

At the conclusion of the review meeting in Granby on January 15, 1982, the equipment was dismantled from the Company's Granby test site and transported to Norman Rogers Airport in Kingston. Installation of the antenna on the mast and of the equipment in the shelter provided by Transport Canada was performed according to plan, and without any technical problems, in spite of the severe weather conditions. The installation was completed in March 1982.

2.2 Design and Construction of a Maintenance Platform

A light wooden platform was designed and installed on the antenna tower, at a height allowing easy access for maintenance and testing of the electronic component parts of the antenna, the lightning conductor, and the aircraft warning light.

This task was successfully completed by the end of March 1982.

2.3 Putting in Operational Preliminary Tests

Work on the prototype installed at Kingston was carried out in the period from April through August 1982, mostly by the team from the Granby plant. In the course of this work, some temporary breadboards were replaced by engineered modules and more detailed tests were taken to ensure a more accurate performance of the equipment. A preliminary demonstration was performed on September 28-29, 1982, as described in the Test Report dated October 8, 1982. This test was carried out in accordance with the Test Procedures, as shown in Appendix 3. The test results left much to be desired as regards the expected performance accuracy and corrective action was recommended to improve the equipment, particularly in the areas of sensitivity and bearing accuracy.

2.4 Corrective Action and the Second Demonstration

As a result of the unsuccessful demonstration, the Company proposed to investigate the problems and to review the design, where necessary. This work was undertaken with the support of Transport Canada under Contract No. 11SD.T8200-2-2541, which took a good part of the winter of 1982/1983 owing to weather conditions and a shortage of staff. A second demonstration was presented to Transport Canada on March 28-30, 1983 and a final test report was prepared in April 1983, showing test results to be acceptable, except for certain azimuth angles where bearing errors were caused by phase detector noise. (see Appendix 2 for test results and Appendix 4 for test procedures).

2.5 Final Tests

The noise problem was eliminated by a minor design change in April 1983 and the DF accuracy test was repeated by the Company. The final test report is given in the supplement of Appendix 2, where the enclosed graphs replace those of the March 1983 test. The performance can now be claimed to be acceptable, providing advantage is taken of the built-in calibration corrections.

2.6 Technical Support

Technical support of Bayly personnel and facilities were provided over the period April 1982 to May 1983 to maintain the equipment operational.

3. CONCLUSIONS AND RECOMMENDATIONS

On the basis of the final test results of April 1983, it can be concluded that the design is capable of giving repeatable azimuth indications of the incoming radio signals, with a sensitivity acceptable for ATC purposes, thus completing the present contract. However, the use of built-in correction tables for the reduction of bearing errors to the specification level was questioned by the Transport Canada representatives as involving additional tasks for the maintenance personnel.

It is quite possible to achieve the desired accuracy without calibration corrections, but not in the first prototype model with its part-breadboard construction. It is therefore recommended that a second equipment be built, and re-packaged as necessary, to improve the heat and radio interference problems, and resembling, as far as possible, the final production units. This work should be undertaken forthwith as a separate task.

APPENDIX 1

PRELIMINARY TEST REPORT

ON THE DF SYSTEM PROTOTYPE

INSTALLED AT KINGSTON AIRPORT

DATE OF TESTS: SEPTEMBER 1982

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ATTENDANCE

Mr. N.E. Rudback	-	Transportation Development Centre (part-time)
Mr. M. Boudreaux	-	Transport Canada (Ottawa)
Mr. R. Leduc	-	Transport Canada (Ottawa)
Mr. Z.A. Krajewski	-	Bayly, Ajax
Mr. F. Baehr	-	Bayly, Ajax
Mr. C. Lapointe	-	Bayly, Granby
Mr. J. Noisseaux	-	Bayly, Granby

Mr. P. Harper (Pilot, Falcon Helicopters Ltd.)

SCOPE

This preliminary field test was intended as a demonstration to the Design Authority of performance of the Prototype Unit of the Doppler Radio Direction Finder for ATC. The main accent in the test was on providing the DF accuracy although the only way was to show the combined effect of the instrumental and field site errors. Other field tests were performed, such as sensitivity, polarization angle, adjacent channel interference and elevation angle, as well as a number of visual checks to show that the operational controls are in order. The tests were carried out mainly as indicated in the System Field Performance Test Procedure, previously submitted, except as otherwise indicated. Observations, conclusions and recommendations were drawn up to indicate the future line of action.

TEST NO. 1 - SYSTEM DF SENSITIVITY (CW MODE)

Summary of Test Procedure

A target transmitter is set at 0° azimuth and its signal strength is adjusted to give a field strength of 3μV/m at the centre of the antenna array as measured with a field strength meter. A minimum of 10 consecutive readings of bearing each are taken at three different test frequencies. Bearing spreads are calculated for each frequency and histograms are plotted to indicate the nature of the spread.

Specification

3μV/m for ±1.5° accuracy

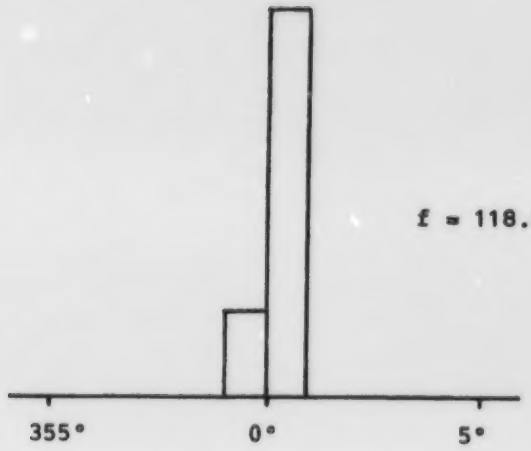
Test Results

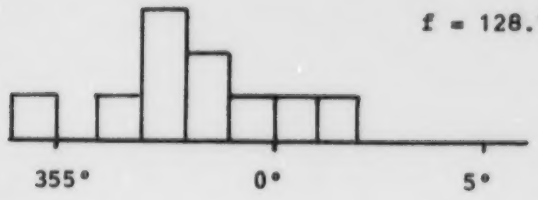
Consecutive Readings	Bearing Readout Degrees Test Frequency MHz 118.25	128.7	133.0	Field Strength 3μV/m
1	0.1	358.7	357.0	
2	0.3	357.3	357.8	
3	359.8	358.1	356.7	
4	359.9	357.3	357.4	
5	0.2	356.1	357.2	
6	0.2	1.4	356.2	
7	0.1	357.6	356.4	
8	0.0	0.5	357.2	
9	0.1	359.1	358.4	
10	0.2	354.8	357.3	
11	0.0		356.4	
Max. Spread	0.5°	6.6°	2.2°	
Aver. offset	0.08°	-1.54°	-2.91°	
r.m.s. error	±0.15°	±1.67°	±0.65°	

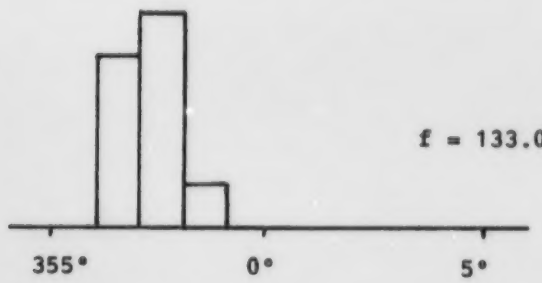
Histogram of Bearing Spread

for 3μV/m signal strength

(target at 0° azimuth)







Observations

At this low level of signal, the bearing readout is flashing intermittently at intervals of 1-5 seconds. This is controlled by a statistical sample analysis which blanks out readings with excessive noise error, presenting only those which are acceptably close to the true bearing. The intermittent flashing may be annoying, as observed on the receiver control panel, but it must be remembered that the operator in the control tower has no such difficulty. A continuous access to the bearing angle is available to him as the bearing is displayed and held automatically on the bearing store readout.

Conclusions

The field strength sensitivity of the system is well in spec. on both sides of the RF band. At the centre of the band, the sensitivity is marginally out of spec., showing approx. 30% of readings affected by noise error.

TEST NO. 2 - EFFECT OF CONTROLLED VARIATIONS IN TEST SIGNAL OPERATING CONDITIONS

Summary of Test Procedure

The purpose of this test is to show the effect of de-tuning the target frequency, the effect of applying AM or FM and the effect of variation of the field strength level. The target transmitter is located at 0° azimuth and the field strength level is maintained at 10μV/m except for the last portion of the test where the level variations are recorded. Simplified plots are given for the deviation of bearing from reference, showing the average and the noise spread for each value of reading.

Specification

This performance evaluation is for information only. There are no contractual spec. restrictions for these test items.

Test Results

1. CW Mode (field strength 10μV/m)

Test Freq. MHz	Bearing Reading (degrees) Min.	Max.	Aver.	Deviation from ref.
128.700	357.3	359.2	358.2(ref.)	0.0
128.003	358.5	1.9	0.2	+2.0
128.006	354.8	359.5	357.0	-1.2
127.997	359.4	2.6	1.0	+2.8
127.994	0.0	1.8	0.9	+2.7

2. AM Mode (field strength 10μV/m, modulation 30% at 1000 Hz)

128.700	357.6	359.4	358.5(ref.)	0.0
127.997	358.2	0.8	359.5	+1.0
127.994	0.3	2.0	1.1	+2.6

3. FM Mode (field strength 10μV/m, 1000 Hz tone)

Test Freq. MHz	Deviation FM kHz	Bearing Reading (degrees) Min.	Max.	Aver.	Change from ref.
128.700	0	358.3	359.9	359.1	0.0
	±1	0.4	2.6	1.5	2.4
	±3	358.6	0.4	359.5	0.4
	±5	359.6	0.7	0.1	1.0

NOTE: The original log table provided for this test was in error, showing de-tuning rather than FM deviation. This has been corrected on the present test.

4. Variation with Signal Strength (freq. 128.7 MHz, CW Mode)

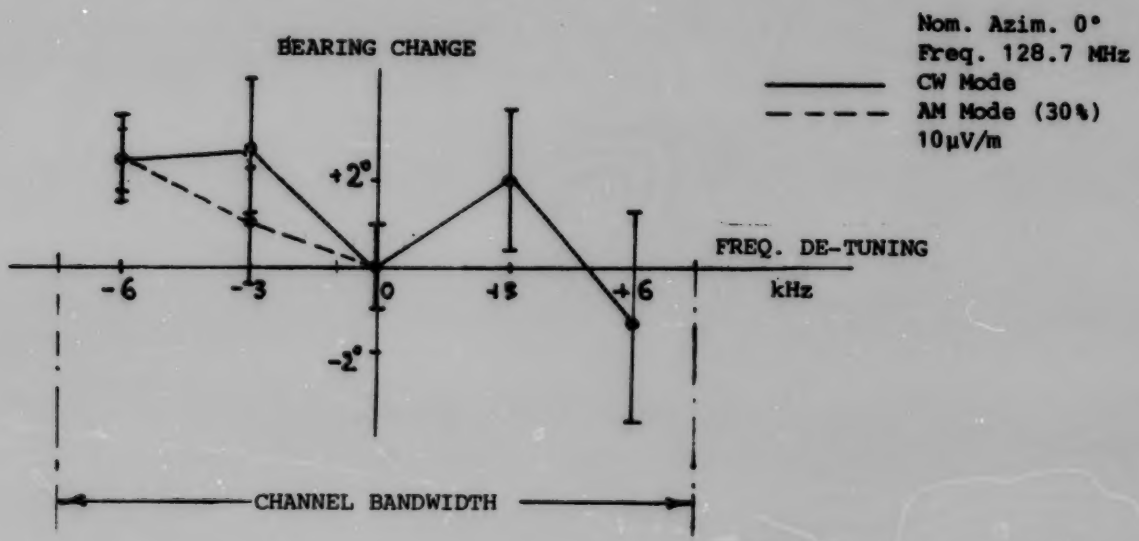
Test Field Strength	Bearing Reading (degrees) Min.	Max.	Aver.	Change from ref.
3μV/m *	354.8	1.4	358.1	-0.5
10μV/m	357.8	359.5	358.6(ref.)	0.0
30μV/m **	358.3	358.8	358.55	-0.05
100μV/m	0.1	0.3	0.2	1.6
1mV/m	0.1	0.3	0.2	1.6
10mV/m	1.1	1.3	1.2	2.6
100mV/m	1.3	1.4	1.35	2.75

* readings taken from sensitivity test

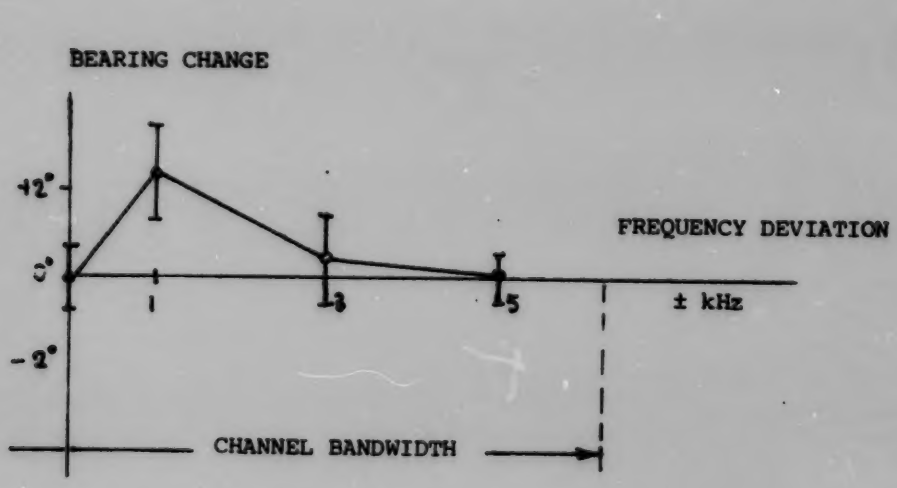
** readings taken from DF accuracy test

NOTE: A wide band power amplifier, preset to +40 dB, was used in conjunction with the signal generator at the target site in order to provide the required field strength for the two highest levels.

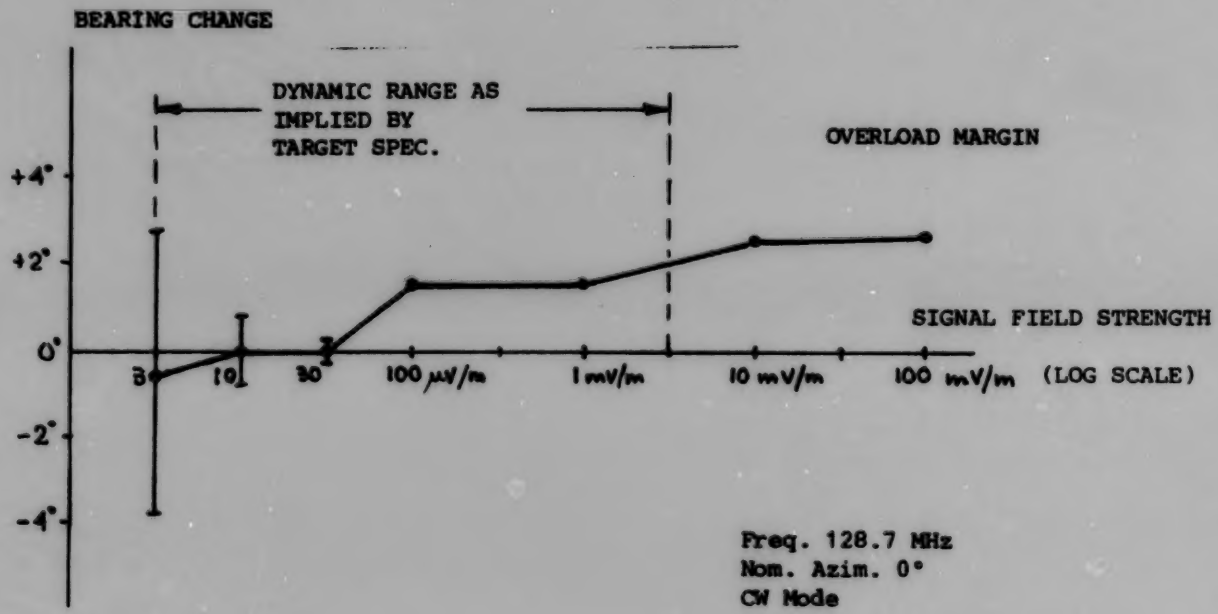
Effect of De-tuning (CW and AM Mode)



Effect of Frequency Modulation



Variation with Signal Strength



Freq. 128.7 MHz
Nom. Azim. 0°
CW Mode

Observations

De-tuning of the target transmitter from the centre of the channel frequency produces bearing errors which are due to the unbalance of the phase ripple in the receiver final i.f. filters. Some improvement can be reached by more careful alignment. The same alignment will also improve the response of FM frequency deviation. On the whole, the performance is remarkably good, considering there is no AFC incorporated in the prototype under test. The intention is to add the AFC feature in the future models, which is expected to reduce the bearing fluctuation with de-tuning to less than ±0.5°.

The signal strength test demonstrates that the system is capable of operating over a dynamic range of 90 dB. This is a considerable achievement.

TEST NO. 3 - DF SYSTEM ACCURACY

Summary of Test Procedure

In this test, a target transmitter is moved around the perimeter of the calibration circle (61 m radius = 25 wavelengths approx.). Bearings are taken at three different frequencies (118.5 MHz, 128.7 MHz and 133.0 MHz) and at two levels of signal strength (30μV/m and 1 mV/m). Reading fluctuations, due to noise, are allowed for by recording minimum and maximum figures and computing the average and the bearing error. A plot of the average errors is drawn for each of the signal strength levels for the three given frequencies. A final calculation is made to determine the reference offset and the RMS error over the entire scan, for each of the graphs separately.

Specification

The contractual specification refers to the instrumental DF accuracy of $\leq \pm 1.5°$. This field test demonstrates a combination of the instrumental DF error plus the test site error. The two component errors cannot be separated in a fixed type of installation, therefore, allowance must be made for the possible contribution of the test site error to the overall results.

TEST RESULTS - REGULAR RUN

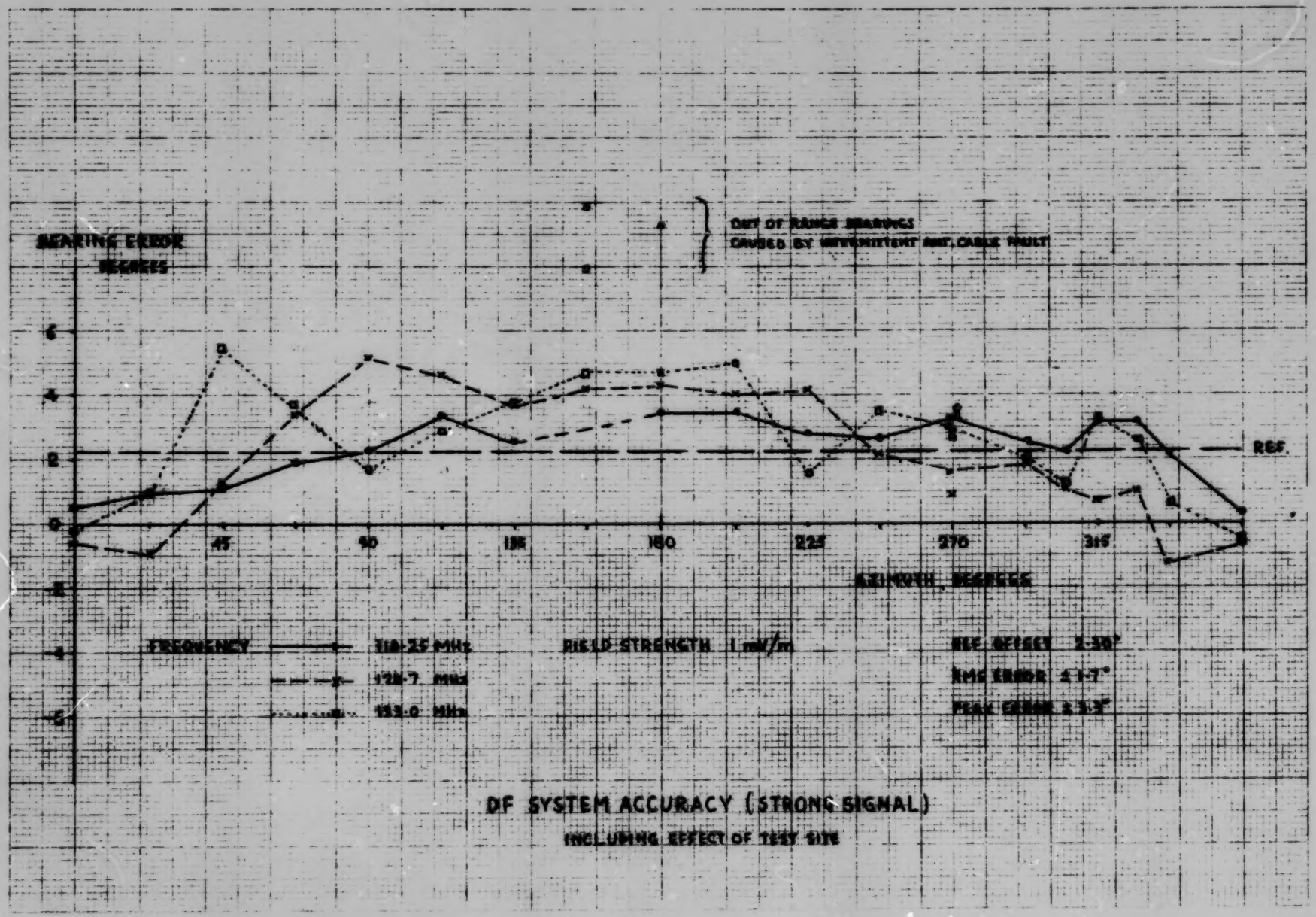
Target Location Azimuth, deg.	Field Strength µV/m	Frequency 118.25 MHz Min.	Max.	Aver.	Error	Frequency 128.7 MHz Min.	Max.	Aver.	Error	Frequency 133.0 MHz Min.	Max.	Aver.	Error
0	1000	0.4	0.6	0.5	0.5	359.3	359.5	359.4	-0.6	359.8	359.8	358.8	-0.2
	30	0.2	0.2	0.2	0.2	358.3	358.8	358.55	-1.45	357.8	358.0	357.9	-2.1
22.5	1000	23.4	23.5	23.45	0.95	21.6	21.6	21.6	-0.9	23.5	23.5	23.5	1.0
	30	23.6	23.8	23.7	1.2	20.0	21.0	20.5	-2.0	22.6	22.6	22.6	0.1
45	1000	46.1	46.1	46.1	1.1	46.2	46.4	46.3	1.3	49.0	52.0	50.5	5.5
	30	46.0	46.1	46.05	1.05	45.2	45.6	46.4	0.4	45.9	47.0	46.5	1.5
67.5	1000	69.4	69.5	69.45	1.95	70.9	71.0	70.95	3.45	71.0	71.5	71.25	3.75
	30	69.1	69.2	69.5	2.0	69.7	71.0	70.35	2.85	68.6	68.9	68.75	1.25
90	1000	92.3	92.3	92.3	2.3	95.2	95.2	95.2	5.2	91.7	91.7	91.7	1.7
	30	91.7	91.8	91.75	1.75	94.7	95.3	95.0	5.0	91.4	91.4	91.4	1.4
112.5	1000	115.9	116.0	115.95	3.45	117.1	117.2	117.15	4.65	115.4	115.5	115.45	2.95
	30	115.2	115.3	115.25	2.75	116.6	117.2	116.9	4.4	114.9	114.9	114.9	2.4
135	1000	137.6	137.6	137.6	2.6	138.7	138.7	138.7	3.7	138.7	138.8	138.75	3.75
	30	137.6	137.7	137.65	2.65	138.3	138.7	138.5	3.5	138.1	138.6	138.35	3.35
157.5	1000	165.4	165.5	165.45	*7.95	161.7	161.7	161.7	4.2	161.9	162.4	162.15	4.65
	30	165.5	165.6	165.55	*8.05	160.5	160.9	160.7	2.2	160.7	160.9	160.8	2.3

*2 NOTE: Suspect readings to be re-checked

TEST RESULTS - REGULAR RUN (Cont'd)

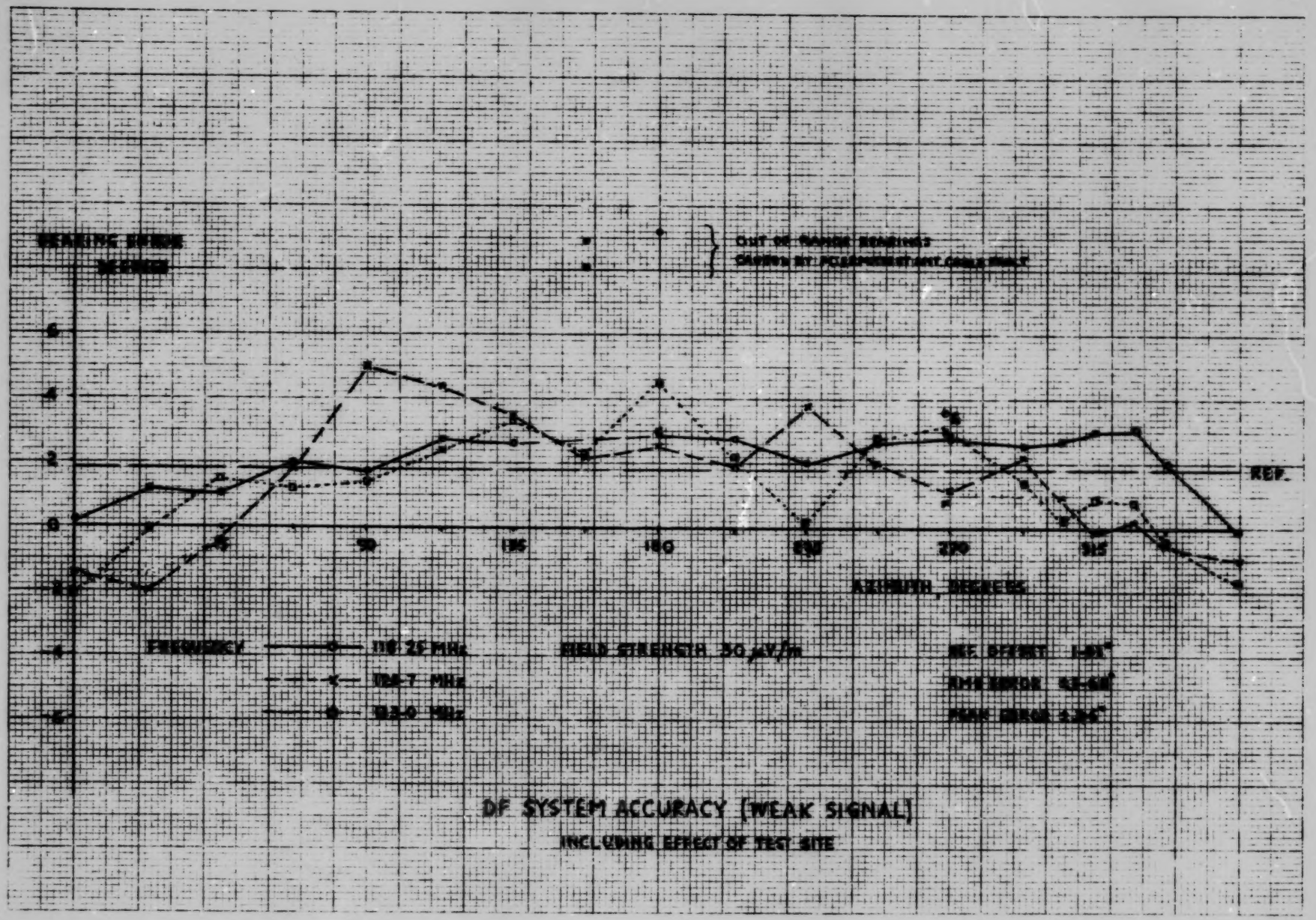
Target Location Azimuth, deg.	Field Strength µV/m	Frequency 118.25 MHz Min.	Max.	Aver.	Error	Frequency 128.7 MHz Min.	Max.	Aver.	Error	Frequency 133.0 MHz Min.	Max.	Aver.	Error
180	1000	189.3	189.3	189.3	*9.3	184.1	184.5	184.3	4.3	184.5	185.0	184.75	4.75
	30	189.2	189.3	189.25	*9.25	182.3	182.8	182.55	2.55	184.4	184.6	184.5	4.5
202.5	1000	205.7	206.3	206.0	3.5	206.5	206.6	206.55	4.05	207.0	208.0	207.5	5.0
	30	205.2	205.3	205.25	2.75	204.0	204.9	204.45	1.95	204.6	204.7	204.65	2.15
225	1000	227.7	228.0	227.85	2.85	229.0	229.3	229.15	4.15	226.5	226.6	226.55	1.55
	30	227.0	227.1	227.05	2.05	228.6	229.0	228.8	3.8	224.9	225.6	225.25	0.25
247.5	1000	250.1	250.3	250.2	2.7	249.6	249.7	249.65	2.15	251.0	251.0	251.0	3.5
	30	250.0	250.3	250.15	2.65	249.3	249.7	249.5	2.0	250.3	250.4	250.35	2.85
270	1000	272.9	272.9	272.9	2.9	270.1	271.7	270.9	0.9	272.6	272.7	272.65	2.65
										BLANK 80%			
	30	272.8	272.9	272.85	2.85	271.5	271.9	271.2	1.2				
		BLANK 20%				BLANK 90%				BLANK 100%			
292.5	1000	295.0	295.1	295.05	2.55	294.3	294.4	294.35	1.85	294.5	294.7	294.6	2.1
	30	295.0	295.1	295.05	2.55	294.5	294.9	294.7	2.2	293.9	293.9	293.9	1.4
315	1000	318.2	318.2	318.2	3.2	315.7	315.8	315.75	0.75	318.1	318.4	318.25	3.25
	30	318.0	318.0	318.0	3.0	314.5	315.3	314.9	-0.1	315.8	316.0	315.9	0.9
337.5	1000	339.6	339.6	339.6	2.1	336.2	336.3	336.25	-1.25	338.1	338.1	338.1	0.6
	30	339.5	339.6	339.55	2.05	336.7	337.2	336.9	-0.55	337.0	337.2	337.1	-0.4

* NOTE: Suspect readings to be re-checked



DF SYSTEM ACCURACY (STRONG SIGNAL)

INCLUDING EFFECT OF TEST SITE



DF SYSTEM ACCURACY [WEAK SIGNAL]

INCLUDING EFFECT OF TEST SITE

Observations - Regular Run

The variation of bearing error with azimuth follows the usual pattern, showing a noticeable quadrantal component which is usually caused by the presence of the cabin situated on the one side of the antenna support mast. The spread of errors with frequency and with the signal level is quite acceptable. Statistical computation of all the readings around the calibration circle gives the following results:

Field Strength	30 V/m	1mV/m
RMS error	1.68°	1.7°
Peak Error	±3.5°	±3.0°
Reference offset	1.83°	2.30

The offset of the reference can be corrected easily in the Receiver Unit by resetting a 'Dipswitch' provided for the exact setting of the North reference. Thus, the REF line can be brought to coincide with the zero axis.

The RMS errors obtained here are including the errors of the test site, even so, they are only slightly higher than the 1.5° specified for instrumental accuracy called for in the contract. In this respect, the results can be claimed to be remarkably accurate.

The peak errors, referred to the REF line, do not exceed 3.5° which is considerably less than the ±6° allowed for by the FAA.

There were two problems observed during the run of this experiment:

- some erratic readings in the sector of 157.5 - 180°
- excessive 'data invalid' blanking at the azimuth of 270°.

Both of these were investigated in detail after the completion of the regular run.

TEST RESULTS - ADDITIONAL READINGS

Target Location Azimuth, deg.	Field Strength µV/m	Frequency 118.25 MHz Min.	Max.	Aver.	Error	Frequency 128.7 MHz Min.	Max.	Aver.	Error	Frequency 133.0 MHz Min.	Max.	Aver.	Error
Bearings at in-between locations (11.25° spacing) and a repeat of 0° azimuth													
0	1000	0.3	0.4	0.35	0.35	359.4	359.4	359.4	-0.6	359.4	359.4	359.4	-0.6
	30	359.8	0.0	359.9	-0.1	358.6	359.4	359.0	-1.0	358.3	358.4	358.35	-1.65
303.75	1000	306.0	306.0	306.0	2.25	304.8	304.8	30.8	1.05	305.0	305.0	305.0	1.25
	30	306.4	306.5	306.45	2.7	304.4	304.8	304.6	0.85	303.9	303.9	303.9	0.15
326.25	1000	329.4	329.5	329.45	3.2	327.2	327.3	327.25	1.0	328.9	329.0	328.95	2.75
	30	329.3	329.3	329.3	3.05	326.7	327.2	326.85	0.25	327.0	327.2	327.1	0.85
Repeat of suggested readings around 180° after repairing an intermittent connection in #16 dipole feeder													
180	1000	183.4	183.6	183.5	3.5	183.5	183.7	183.6	3.6	184.3	184.3	184.3	4.3
	30	182.9	182.9	182.9	2.9	182.2	184.0	183.1	3.1	185.0	185.7	185.35	5.35
157.5	1000	166.2	166.6	166.4	8.9	161.9	162.0	161.95	4.45	162.3	162.4	162.35	4.85
	30	166.2	166.4	166.3	8.8	161.5	162.0	161.75	4.25	162.1	162.3	162.2	4.7

TEST RESULTS - CHECK ON THE BLANKING AT 270°

Target Location	Field Strength µV/m	Frequency 118.25 MHz				Frequency 128.7 MHz				Frequency 133.0 MHz			
		Min.	Max.	Aver	Error	Min.	Max.	Aver	Error	Min.	Max.	Aver	Error
271°	1000	273.6	273.6	273.6	2.6	BLANK 95%		272.7	1.7			273.5	2.5
	30	273.5	273.6	273.55	2.55	BLANK						273.5	2.5
272°	1000	274.4	274.5	274.55	2.55	273.6	273.6	273.6	1.6	274.3	274.3	274.3	2.3
	30	274.4	274.4	274.4	2.4	273.8	273.9	273.85	1.85	274.5	274.5	274.5	2.5
270°	500			272.9	2.9			272.2	2.2			272.8	2.8
Radius 122 m	30	BLANK 18%		272.5	2.5	BLANK 95%		271.5	1.5	BLANK 90%		272.4	2.4
	15	BLANK				BLANK				BLANK 95%		270	-
269°	1000	272.6	273.9	273.25	4.2	271.6	271.6	271.6	2.6	272.7	273.3	273.0	4.0
	30	273.6	273.7	273.65	4.65	BLANK 90%		270.8	1.8	272.9	273.1	273.0	4.0
										BLANK 95%			

Blanking Anomaly at 270°

With the target transmitter at 270°, the bearing reading was blanked out for all the weak signals, beginning to show intermittently at 100μV/m or higher. An investigation was made of this anomaly, which had the symptom of poor sensitivity at this azimuth angle. The following tests were performed to establish the nature of the anomaly:

1. The phase detector waveform was examined for different field strength levels - a clean-cut, workable waveform was observed even down to 3μV/m. This removes any doubts of DF receiver performance.

2. The field strength intensity was recalibrated for the 270° position, showing no change from that at other angles. This eliminates any questions of local terrain damping.

3. The target transmitter was moved tangentially by 2 metres in each direction from the 270° position (approx. ±2°). The bearing readings became acceptable with only partial blanking at certain frequencies.

4. The target transmitter was moved radially to double the distance from the DF array (from 61 m to 122 m). Generator signal level was increased by 6 dB to re-create the same field strength intensity at the DF antenna as for the other readings. In this position of the target there was no noticeable improvement in blanking.

In conclusion, the blanking anomaly can be tied down to a narrow sector of <±2° around the 270° position, and the blanking must be caused by the bearing processor. A later examination of the software has provided a simple explanation pointing to an irregularity in the program which has been overlooked in the earlier tests.

The function of the bearing processor is to sample a number of scans of the antenna array and to compute, by Fourier analysis, the bearing angle for each successive scan. In the next operation, the processor calculates an average bearing and also the spread of deviations between the individual readings. If the spread exceeds a certain limit (say 10°) the data is considered invalid and the readout is blanked out.

Consider now that the target is near zero degrees and a bunch of readings is obtained with a spread of, say, ±3 °. These may be, for example:

0.1, 2.9, 358.2, 1.2, 359.5, 1.5, 358.3, 358.7

Average: 180.05

Max. Spread: +179.95 - 179.45

It is clear that the numerical average does not represent the bearing and the spread of deviations will exceed, by far, the limits acceptable by the blanking circuit. This type of bearing readout will be blanked out entirely.

Now, the interesting fact is that the Fourier analysis reference in the present bearing processor is set to start the computation at -90° (or 270°) and not at the mechanical reference zero. This is why the blanking anomaly is transferred to the 270° location.

Having recognized the problem, the remedy can be incorporated in the software by adding 360 to figures less than 10 and averaging as usual. The final bearing readout will then have 360 subtracted if it is in excess of 359.9.

This proposed change would add one more advantage to the planned development of a new bearing processor.

Tests at Positions Inside the Dipole Spacings

In order to verify the operation of the system at target positions other than the dipole intervals, a couple of tests have been added at 302.25° and 326.25°, - the 11.25° points halfway between the dipoles. The results fall into the general pattern of bearing errors as can be seen from the graphs.

A repeat of the 0° readings has been made to confirm that the DF equipment has not suffered any change over the period of testing. These results are very close to the readings obtained at the beginning of the test.

Erratic Readings in the 157.5° - 180° Sector

Erratic bearing readings, of up to 9°, were obtained at some points in the 157.5 and 180° positions of the target. These were re-tested after completion of the regular run and an intermittent fault was observed on one of the dipole feeder cables (#16) leading to the antenna commutator switch. Repairing the cable has returned the equipment to normal operation, except for the 118.25 MHz test at the 157.25° angle. The latter was later corrected by receiver phase adjustment which should have been done anyway after the cable repair.

For the purpose of this test, it is proposed that these erratic readings should be disregarded.

TEST NO. 4 - POLARIZATION ANGLE

Summary of Test Procedure

Bearing readings are taken first with the transmitter antenna vertical and then inclined at 45° in a tangential plane to the DF array. The bearing change is noted as the result in change of polarization of the incoming wave. Tests were repeated at three different frequencies in the RF band and at five different locations of the target transmitter around the calibration circle.

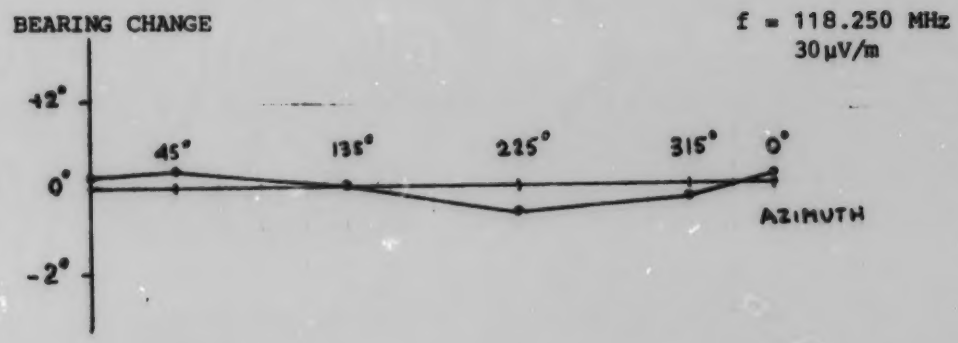
Specification

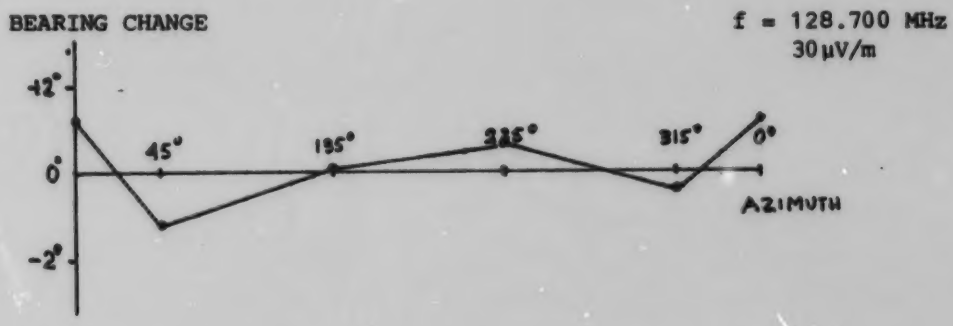
±1° approx.

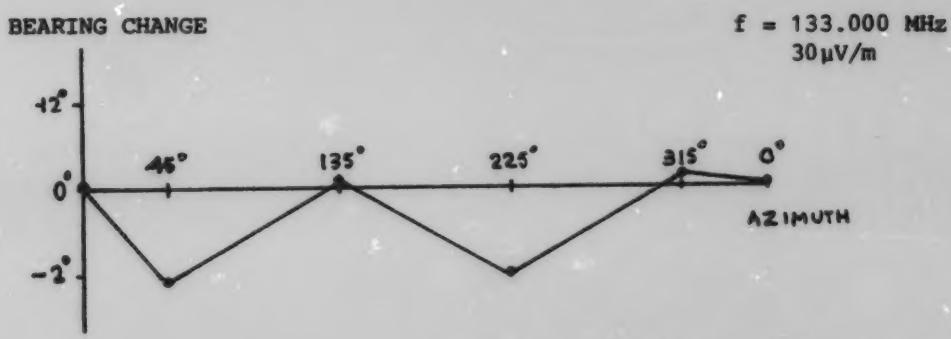
Test Results (Field Strength 30μV/m)

Transmitter Location and Freq.	Bearing Vert. Polariz.			Bearing 45° Polariz.			Bearing Change from Vertical
	Min.	Max.	Aver.	Min.	Max.	Aver.	
118.250 MHz							
0°	0.1	0.1	0.1	0.2	0.4	0.3	0.2°
45°	45.9	46.0	45.95	45.5	45.7	45.6	0.35°
135°	136.3	136.5	136.4	136.4	136.4	136.4	0.0°
215°	227.0	227.2	227.1	226.4	226.6	226.5	-0.6°
315°	317.4	317.5	317.45	317.1	317.3	317.2	-0.25°
128.7 MHz							
0°	357.5	358.4	357.95	358.6	359.7	359.15	1.2°
45°	46.0	46.5	46.25	44.8	45.5	45.15	-1.1°
135°	138.2	138.6	138.4	137.6	139.3	138.45	0.05°
215°	228.5	229.0	228.75	227.2	228.8	228.0	0.75°
315°	314.7	315.1	314.9	314.0	315.2	314.6	-0.3°
133.7 MHz							
0°	359.4	359.5	359.45	359.3	359.5	359.4	0.05°
45°	47.0	49.5	48.25	46.0	46.3	46.15	-2.1°
135°	137.6	137.7	137.65	137.7	137.9	137.8	0.15°
215°	225.3	226.9	226.1	224.0	224.2	224.1	-2.0°
315°	315.8	315.9	315.85	316.0	316.0	316.1	0.25°
				Overall rms error			±0.91°
				Shift of average			-0.22°

Effect of 45° Polarization Change on Bearing







Observations and Conclusions

The effect of polarization change is quite negligible except at azimuth angles of 45° and 225° where the position of the cabin is suspected to cause horizontally polarized reflections. The errors are larger at the top of the RF band indicating that the reflecting elements (possibly electrical conduits) are resonant close to that frequency. The overall average rms error is well within the spec. The shift of average of -0.22° is of interest as it indicates the displacement of the centre of the test transmitter antenna, as it is rotated through the 45° (approx. 20 cm).

TEST NO. 5 - ADJACENT CHANNEL BREAKTHROUGH

Original Test Program

The purpose of this test is to evaluate the interference caused by the presence of a strong signal in one of the adjacent frequency channels. The original procedure prepared for this test was to have a weak signal transmitted on the wanted channel in an azimuth position of, say, 0° and a strong signal radiated from a second transmitter at 90° away from the first. The frequency of the strong transmitter is then tuned in away from the wanted channel and bearing distortion is then recorded against the frequency de-tuning. This test has proved to be impractical because the bearing processor now has a built-in automatic rejection of any readings that are out of order (as determined by a wide scatter or spread of deviations). Adjacent channel breakthrough, when observable, is producing such a scatter due to scan harmonic mixing and, therefore, causes the bearing reading to be blanked out.

Summary of Revised Test Procedure

A more meaningful test was substituted to show how strong the unwanted signal has to be to cause interference at a given channel spacing. The two transmitters were located, as before, at 90° to each other. The wanted signal was transmitted at 118.25 MHz from an azimuth of 247.5° and with a field strength of 10μV/m. The interfering transmitter was placed at 337.5° and tuned first one channel away and then two channels away. Its level of interfering transmission was varied in 10 dB steps and readings were taken of the variation of bearings of the transmitter No. 1.

Specification

$\leq$1° error with adjacent channel signal up to 50 dB above wanted signal but not exceeding 3mV/m.

Test Results

Azimuth deg.	Freq. MHz	Field Strength µV/m	dB above Tx.1	Bearing Reading (deg.) Min.	Max.	Aver	Change
Transmitter No. 1							
247.5	118.25	10	Tx.2 OFF	251.6	251.9	251.75	REF
Transmitter No. 2							
337.5	118.275	100	20	253.0	254.2	253.6	1.85
	(1 Chan.	300	30	251.0	254.0	252.5	0.75
	away)	1000	40	BLANKED OUT			
337.5	118.300	100	20	252.1	253.5	252.8	1.05
	(2 chan.	300	30	254.2	255.0	254.6	2.85
	away)	1000	40	253.9	257.5	255.7	3.95
		3000	50	BLANKED OUT			
337.5	118.325 (3 chan. away)	3000	50	252.1	254.8	253.0	1.25

Observations and Conclusions

It is considered that the blanking feature has its good point in not distracting the operator with erratic bearings. The immunity from adjacent channel interference does not fully meet the target specification. The present design continues to give the wanted bearing under the following interference conditions:

One channel away - interfering signal 30 dB above wanted signal

Two channels away - interfering signal 40 dB above wanted signal

Three channels away - interfering signal 50 dB above wanted signal

This performance is considerably better than that encountered in equipments in present use. Further improvements are difficult to achieve without compromising the speed of response. An overall upgrading of 10 dB may be predicted for the next generation.

TEST No. 6 - TWO TEST SIGNALS IN THE SAME CHANNEL

Summary of Test Procedure

As distinct from Test No. 5, this test is to show the effect of interference of a second signal source tuned close to the same frequency as the wanted signal. This test was carried out directly after Test No. 5, and under the same conditions regarding location of transmitters, except that both targets were tuned to 118.25 MHz.

Specification

There is no contractual specification for this feature. It has been known from experience of other Doppler DF systems that the stronger of the two signals 'pulls-in' the bearing quite rapidly, a difference of 9-10 dB being usually sufficient for the changeover each way.

Test Results

Azimuth Deg.	Frequency MHz	Field Str. µV/m	dB above Tx.1	Bearing Reading deg. Min.	Max.	Aver	Change
Transmitter No. 1							
247.5	118.25	30	Tx.1 OFF	250.4	250.4	250.4	REF
Transmitter No. 2							
337.5	118.25	3	-20	250.1	250.5	250.3	-0.1
		10	-10	30%	BLANK	250.0	-0.4
		30	0	100%	BLANK	-	-
		100	10	339.8	340.6	340.2	0.3
		300	20	339.8	340.0	339.9	0.1
		1000	30	339.8	339.8	339.8	REF

Conclusion

A complete changeover is observed in less than ±10 dB as expected.

TEST NO. 7 - ELEVATION TEST

Revised Test Procedure

The elevation test was intended to demonstrate that accurate bearings can still be obtained from targets above the ground level and to show the operation of the 'overhead' pass indicator. Upon discussion with the crew of the helicopter rented for the experiment, it became clear that the original test procedure had to be modified drastically. The main reason was the restriction of flight ceiling over the airport (500 ft. max.), the inability of the helicopter to rise vertically to the requested heights and, finally, the difficulty of maintaining a stand-still position in mid-air with the accuracy required in the measurements.

In order to allow for these factors, the test procedure was modified to make the helicopter approach the DF site in an accurate straight line, keeping the sight of a radio tower on the edge of the airport in line with the DF antenna mast. A constant height of 500 ft. above ground level was maintained. The elevation angle of the helicopter was measured by a theodolite up to 45° above, which a more coarse measure was adopted, using a straight rule and a protractor. The helicopter was made to come to a brief stand-still at the points where the measurements were taken. Several flight approaches had to be made because it was difficult to hold the helicopter still in the easterly wind blowing across its path.

Specification

There is no direct contractual specification for this test, except the requirement of the 'overhead' alarm to operate when the plane is above the 60° elevation. However, it is understood that the equipment must be operational for targets from the ground level up to 60° elevation.

Test Results

Frequency of the helicopter transmitter: 127.8 MHz (CW)

Strength of transmission: approx. 5 W

Test No	Elevation Angle		Height of Approach ft.	Bearing Reading		Deviation from Aver.		Notes
1	15°	Measured with theodolite (±0.5°)	300	353.4	Aver 355.3	-1.9	—	helicopter distant above wooded area
2	15°		500	357.4		2.1		
3	30°		500	354.5		-0.8		
4	45°		500	356.1		0.8		
5	66°	Measured with protractor (±2°)	500	Blank				
6	45°		500	Blank				
7	70°		500	Blank				
8	90°		500	Blank				
9*	45°		500	183.1			—	target position inaccurate since DF tower no longer in sight

* NOTE: Test 9 was made by flying over the DF site and continuing in an approximate straight line to determine the angle at which a valid bearing will appear.

Observations and Conclusions

A major difficulty in this test was to maintain communication with the pilot because of the engine noise in the helicopter cabin. For the future, it is suggested that a captive meteorological baloon may be more convenient. The test has demonstrated full operational capability of the DF system for elevation angles from 0° to 45°. Above this point, noise became excessive and the bearing reading was blanked out. This noise is due to the reflections from the helicopter rotor and the weakening of the transmission in the downward direction. A better response is expected from planes at higher altitude.

The 'overhead' alarm light could not be tested since it is disconnected in the present bearing processor program.

OTHER TESTS AND OBSERVATIONS

Notes

The tests described here were carried out on the day preceding the final test by the Company, with kind co-operation of the airport Air Traffic Control personnel. They were not witnessed, in person, by the TC representatives from Ottawa.

1. Audio Channel Operation

A minor fault developed on the audio channel in the week prior to the test. This was duly corrected and the audio channel was left fully operative, both in the local and the remote control sites.

2. Emergency Channel Operation

A crystal module (151.5 MHz), which was part of the emergency channel receiver, was found out of tune and returned to the manufacturers. Unfortunately, it could not be repaired in time for the final test. As a substitute, the Company connected up a signal generator to enable the emergency channel to perform in a normal fashion until the crystal can be re-fitted. The receiver threshold has been adjusted to a field strength level of 3μV/m and a test has been made with the co-operation of the airport tower to verify the emergency alarm and trigger action. The crystal module is expected to be returned in 2-3 weeks time.

3. Test Injection

The system test arrangement is not fully operational, giving readings with substantial errors due to insufficient shielding of the feeder cables. This can be corrected, but it requires 2-3 days work and the use of a rented 'cherry picker'.

4. Frequency Mode Selection

Frequencies other than those pre-selected by the pre-set channel push-button are obtained by consecutive dialing of the six-digit number in the 'frequency mode' position. Performance of this function at the receiver unit has caused progressively increasing problems as the push-button switches started to show signs of wear and the 'bounce' and 'scratch' noise was causing multiple, instead of single, digit commands. This problem does not show at all at the operator's control unit, since there is a 0.1 sec. transmission lag before the synthesizer selection circuit is activated. The matter can be corrected simply by increasing the time constant of the latching trigger so as to make the circuit insensitive to bouncing and scratching of the contacts. There is no 'bounce' effect in selecting the pre-set channels.

5. Bearing Store

The bearing store, provided in the operator's control/display unit and the associated readout, are fully operational in both the manual and automatic positions.

6. Operation from the Control Tower

Operation of the DF system was observed at the Control Tower over a period of time of at least 1 hour. The performance was considered very satisfactory, showing indications of stable bearings on the incoming traffic and the control tower transmission. No disturbance was observed from noise interference, the 'data valid' blanking performing as required. The bearing store, in manual position, was holding bearing readings on transmissions of short duration as expected. Channel and frequency selection was obtained as dialed. Voice output was available as required on a loudspeaker provided.

CONCLUSIONS AND RECOMMENDATIONS

The results of the final test conform, very closely, those obtained on the preliminary test of August 12, 1982, with the exception that the 'data valid' operation has been improved in the software of the bearing processor. The present arrangement does not allow display of erratic bearings on an output of noise in the absence of a signal. The DF accuracy is very good for the size of antenna and the type of installation and the dynamic range of the system is remarkably wide, allowing for operation in the presence of very strong interference. Adjacent channel breakthrough may be short of the target specification, but it is a great improvement on the former types of equipment. The operational aspects from the operator's control unit are entirely functional for normal ATC routines.

In conclusion, it is proposed that the equipment remains at the present site for an operational evaluation for a period of several months, so as to show any possible problems over the winter period.

For this purpose, it is recommended that the following repairs and corrections are incorporated as soon as possible:

1. Remove effect of contact bounce in frequency selection mode.

2. Replace the LO crystal in the emergency receiver.

3. Reset the 'North' position correctly, allowing for the offset of the calibration curves obtained in this test.

4. Incorporate an automatic 'reset' for the bearing processor to avoid shut-off after every power failure.

APPENDIX 2

FINAL TEST REPORT

ON THE DF SYSTEM PROTOTYPE

INSTALLED AT KINGSTON AIRPORT

DATE OF TESTS: MARCH 1983

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ATTENDANCE

Mr. M. Boudreaux	-	Transport Canada (Ottawa)
Mr. B. Laflamme	-	Transportation Development Centre (Montreal)
Mr. R. Menkal	-	Bayly Ajax (part-time)
Mr. Z.A. Krajewski	-	Bayly, Ajax
Mr. F. Baehr	-	Bayly, Ajax
Mr. C. Lapointe	-	Bayly, Granby
Mr. R. Anderson	-	Bayly, Ajax
Mr. W. Ng	-	Bayly, Ajax

SCOPE

This final field test was intended as a demonstration to the Design Authority of performance of the Prototype Unit of the Doppler Radio Direction Finder for ATC, following the elimination of problems indicated in the preliminary tests of September 1982. In this test, a precision bearing was installed allowing the antenna to be rotated on top of the mast, this being the only way to show separately the effect of the instrumental and field site errors. Other field tests were performed, such as sensitivity, polarization angle, adjacent channel interference and elevation angle, as well as a number of visual checks to show that the operational controls are in order. The tests were carried out mainly as indicated in the System Field Performance Test Procedure, submitted in March 1982, except as otherwise indicated. Observations, conclusions and recommendations were drawn up to indicate the future line of action.

TEST NO. 1 - SYSTEM DF SENSITIVITY (CW MODE)

Summary of Test Procedure

A target tran mitter is set at 0° azimuth and its signal strength is adjusted to give a field strength of 3μV/m at the centre of the antenna array as measured with a field strength meter. A minimum of 10 consecutive readings of bearing each are taken at three different test frequencies. Bearing spreads are indicated for each frequency and compared with the specification.

Specification

3μV/m for ±1.5° accuracy

Test Results

Field Strength μV/m	Test Frequency MHz	Bearing Readout ° Min.	Max.	Bearing Error ° Min.	Max.	Spread (Spec. Limit 3.0°)
3	118.25	358.8	359.3	-1.2	-0.7	0.5
3	128.6	359.2	359.8	-0.8	-0.2	0.6
3	133.0	354.3	356.3	-5.7	-3.7	2.0
10	128.7	352.5	357.0	-7.5	-3.0	4.5
20	128.7	358.8	359.7	-1.2	-0.3	0.9
15	128.7	357.4	359.0	-2.6	-1.0	1.6

Note

Results of the sensitivity test are well within the specification limit, except for the frequency of 128.7 MHz where the readings are affected by an outside interference.

TEST NO. 2 - EFFECT OF CONTROLLED VARIATIONS IN TEST SIGNAL OPERATING CONDITIONS

Summary of Test Procedure

The purpose of this test is to show the effect of de-tuning the target frequency, the effect of applying AM with de-tuning, and the effect of variation of the field strength level. The target transmitter is located at 0° azimuth and the field strength level is maintained at 10μV/m except for the last portion of the test where the level variations are recorded. A simplified plot is given for the deviation of bearing from reference when changing the signal strength, showing the average and the noise spread for each value of reading.

Specification

This performance evaluation is for information only. There are no contractual specification restrictions for these test items.

Test Results

1. CW Mode, Field Strength 10μV/m

Test Freq. MHz	Bearing Reading ° Min.	Max.	Reading ° Mean	Change ° from ref.
128.600	0.4	0.6	0.5	ref.
128.603	0.1	0.3	0.2	-0.3
128.606	357.2	0.7	359.0	-1.5
128.597	0.2	0.5	0.3	-0.2
128.594	0.7	0.9	0.8	+0.3

2. AW Mode, Field Strength 10μV/m. Test Frequency 128.6 MHz

Mod. Freq. Hz	% Mod.	Bearing Reading ° Min.	Max.	Reading ° Mean	Change ° from ref.
	CW	0.4	0.6	0.5	ref.
1000	30%	0.4	0.6	0.5	0.0
400	30%	0.3	0.6	0.45	-0.05
1000	60%	0.0	0.5	0.25	-0.25
1000	100%	358.4	0.6	0.0	-0.5

3. AM Mode, Effect of De-tuning, Field Strength 10μV/m, AM 30% at 1 kHz

Test Freq. MHz	Bearing Reading ° Min.	Max.	Reading ° Mean	Change ° from ref.
128.600	0.4	0.6	0.5	
128.603	359.9	0.2	0.05	-0.45
128.605	359.4	0.5	0.25	-0.25
128.606	359.3	1.2	0.25	-0.25
128.594	0.7	1.0	0.85	+0.35
128.597	0.2	0.4	0.3	-0.2

4. FM Mode, Effect of Modulation and De-tuning
Field Strength 10μV/m. FM Deviation 3 kHz, Tone 1 kHz

Test Freq. MHz	Bearing Reading ° Min.	Max.	Reading ° Mean	Change ° from ref.
128.600 CW	0.4	0.6	0.5	ref.
128.600 FM	0.2	0.4	0.3	-0.2
128.603	358.7	359.5	359.3	-1.2
128.605	357.9	358.5	358.2	-2.3
128.597	0.3	0.5	0.4	-0.1
128.594	0.3	0.5	0.4	-0.1
128.592	0.4	0.8	0.3	-0.2
128.590	0.5	0.8	0.65	+0.15
128.588	358.9	1.5	0.2	-0.3

5. Effect of Signal Strength. Test Frequency 128.6 MHz, CW Mode

Sig. Gen. Level dBm	Signal Strength μV/m	Bearing Reading ° Min.	Max.	Reading ° Mean	Change ° for ref.
-42	3	359.3	359.9	359.6	-0.8
-32	10	0.1	0.3	0.2	ref.
-22	30	0.3	0.6	0.45	0.25
-12	100	0.7	0.9	0.8	0.6
-2	300	0.8	0.8	0.8	0.6
0	360	0.9	1.0	0.95	0.75
+3	510	2.6	2.7	2.65	2.45
+5	660	2.6	2.7	2.65	2.45
+8	1000	2.6	2.7	2.65	2.45

See graphical presentation in Fig. 1

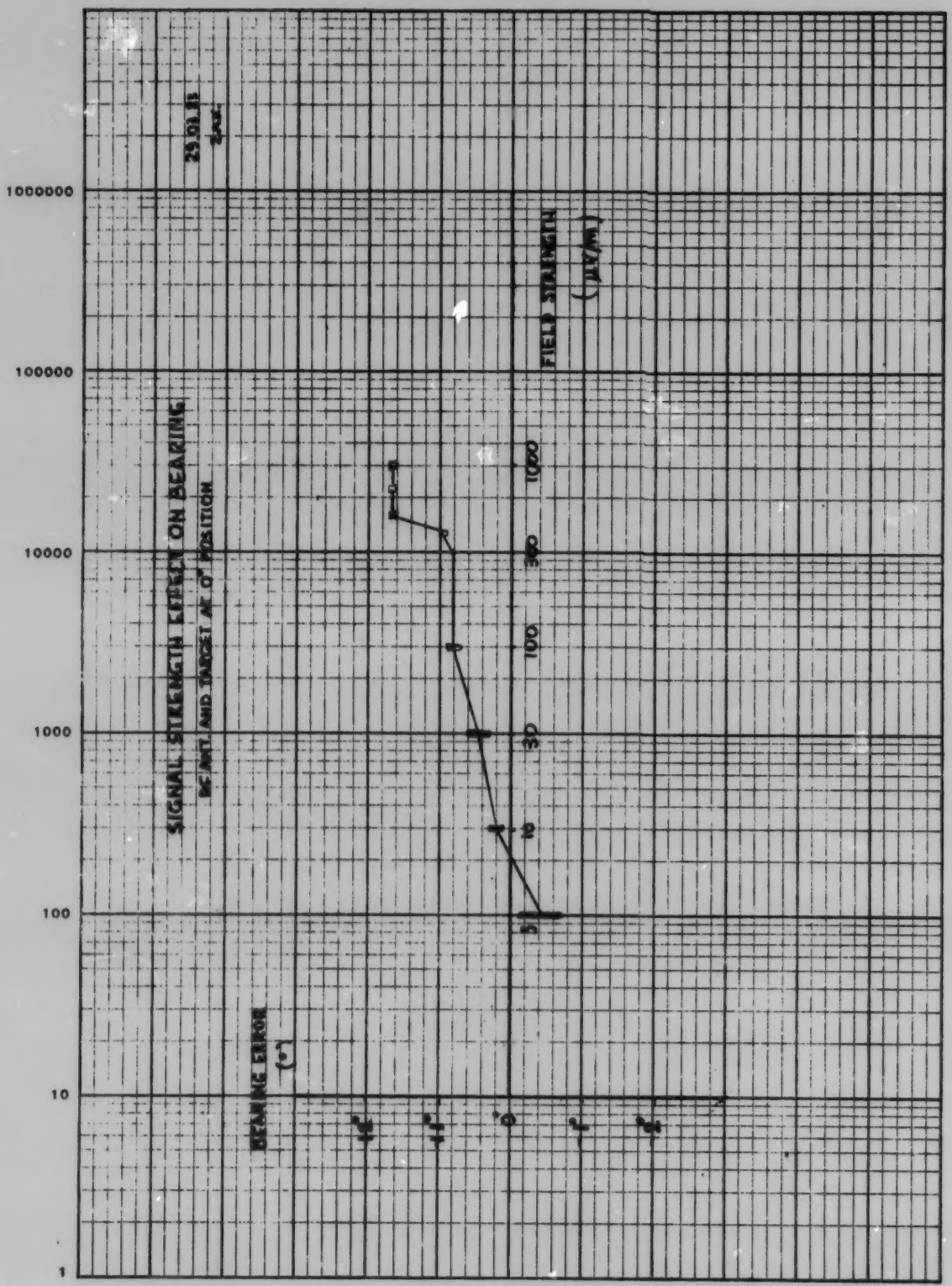

SIGNAL STRENGTH REMAIN ON BEARING
RC ANT. AND TARGET AT 0° POSITION
FIELD STRENGTH (μV/m)
BEARING ERROR (°)
1000000
100000
10000
1000
100
10
1
1000
300
100
30
10
3
1
0

FIG. 1

TEST NO. 3A - DF SYSTEM INSTRUMENTAL ACCURACY

Summary of Test Procedure

The purpose of this test is to establish the relative bearing errors due to the DF system alone, as if installed at an ideal site. This can be achieved by keeping the target transmitter at a fixed location and rotating the DF antenna, thus maintaining the field site error at a fixed value for each test frequency. The target is mounted at the 0° location of the 61m radius calibration circle (North position). The antenna is rotated on a specially designed mechanical bearing provided with precision stop points every 11.25 degrees, giving a total of 32 positions for calibration. At each antenna position, bearing readings are taken for three test frequencies (118.25 MHz, 128.6 MHz and 133.0 MHz) and for three levels of field signal strength (3μV/m, 30μV/m and 1 mV/m). Minimum and maximum reading figures are recorded for each case and a plot is made of the computed bearing error spreads and averages.

Specifications

The target specification calls for an instrumental accuracy of the DF System of ±1.5°. This allows for a maximum spread of 3 degrees between the lowest and highest error readings for each frequency. It will be noted that a different average zero offset may be observed for each test frequency allowing for a site re-radiation error of the target transmitter.

Test Results

The results of this test are shown graphically in the three following sheets, arranged by levels of field strength of the transmitted test signal.

Fig. 2 - DF System Instrumental Accuracy by Antenna Rotation, F.S. 3μV/m

Fig. 3 - DF System Instrumental Accuracy by Antenna Rotation, F.S. 30μV/m

Fig. 4 - DF System Instrumental Accuracy by Antenna Rotation, F.S. 1mV/m

FIG. 2

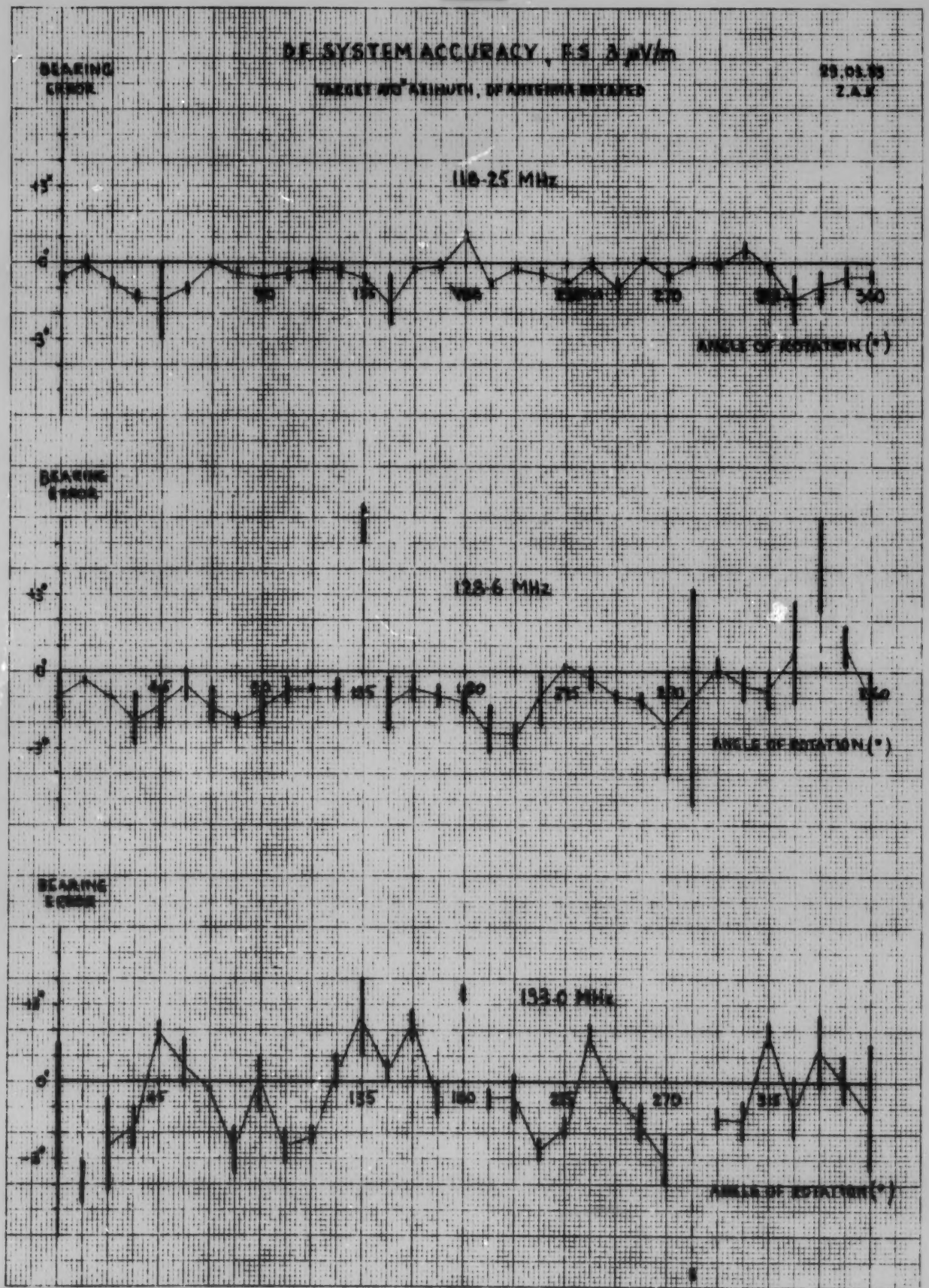
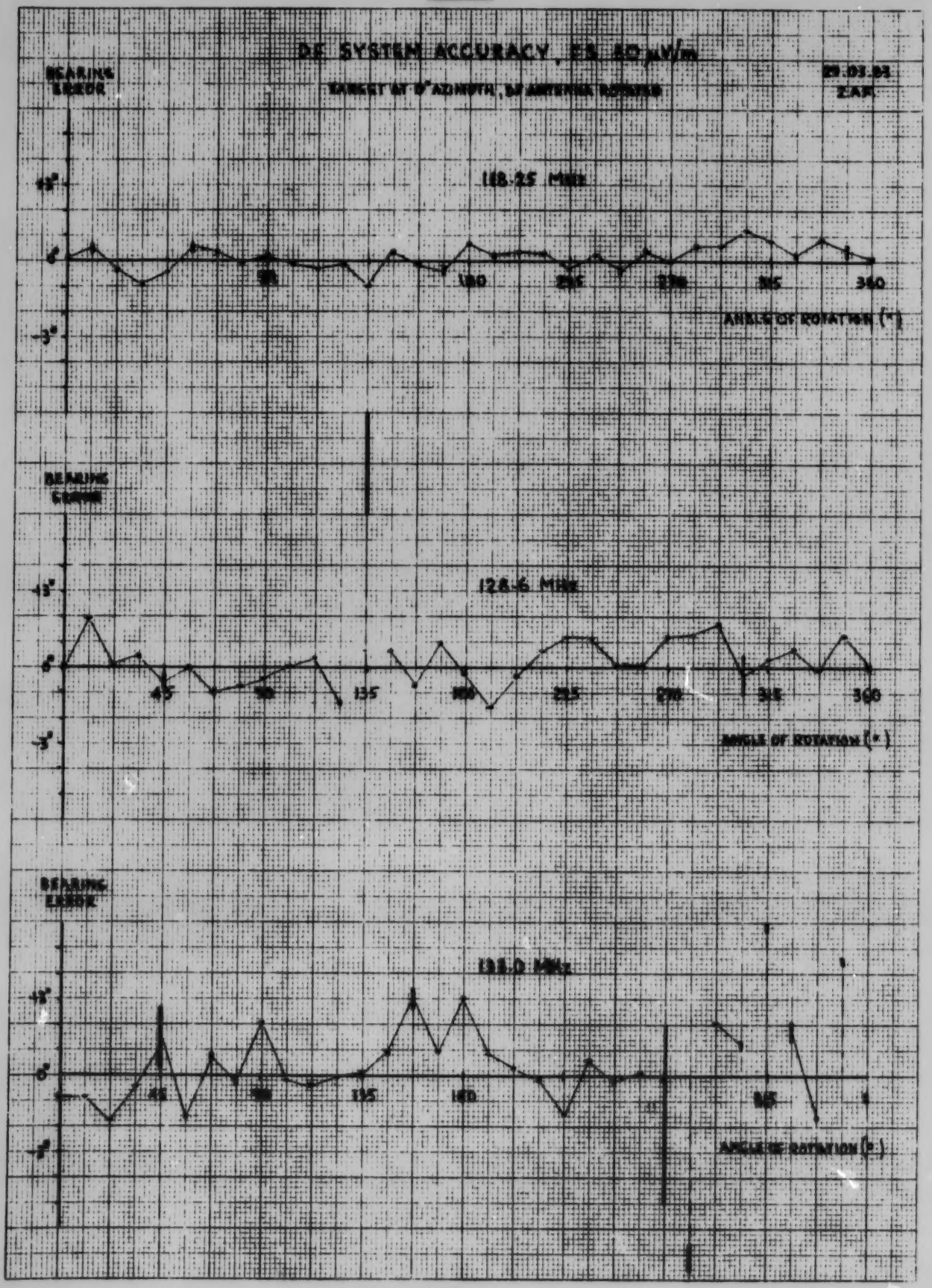
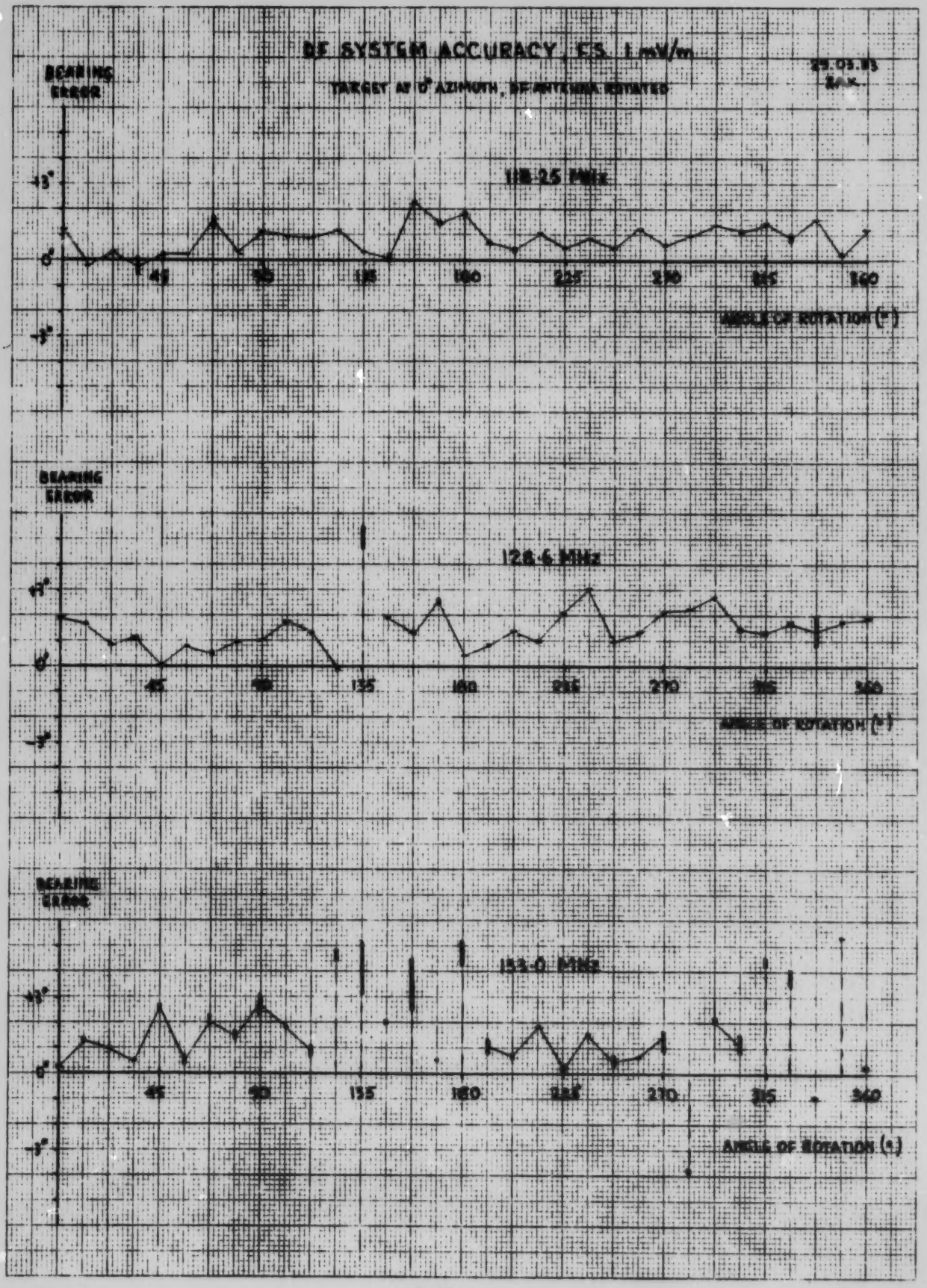

DF SYSTEM ACCURACY, ES A μV/m
TARGET AND AZIMUTH, DF ANTENNA ROTATED
BEARING ERROR
118-25 MHz
+3°
0°
-3°
ANGLE OF ROTATION (°)
128-6 MHz
133-0 MHz
45
135
180
270
340

FIG. 3



46 1513
K+E 10 X 10 TO THE CENTIMETER
KEUFFEL & ESSER CO

FIG. 4


RF SYSTEM ACCURACY, ES. 1 mV/m
TARGET AT 0° AZIMUTH, RF ANTENNA ROTATED
BEARING ERROR
118.25 MHz
+3°
0°
-3°
45
90
135
180
225
270
315
360
ANGLE OF ROTATION (°)
BEARING ERROR
128.6 MHz
+3°
0°
-3°
45
135
180
270
ANGLE OF ROTATION (°)
BEARING ERROR
133.0 MHz
+3°
0°
-3°
45
135
180
270
315
360
ANGLE OF ROTATION (°)

TEST NO. 3B - DF SYSTEM SITE ACCURACY

Summary of Test Procedure

In this test, a target transmitter is moved around the perimeter of the calibration circle (61 m radius = 25 wavelengths approx.). The DF Antenna is set in 2000 degrees position and bearings are taken at three different frequencies (118.25 MHz, 128.7 MHz and 133.0 MHz) and at three levels of signal strength (3μV/m, 30μV/m and 1mV/m). Reading fluctuations, due to noise, are noted by recording minimum and maximum figures, and computing the average and the bearing error. A plot of fluctuations, and of the average errors, is drawn for each of the signal strength levels for the three given frequencies.

Specification

The accepted specification of the field site DF accuracy is ±3°. This field test demonstrates a combination of the instrumental DF error plus the test site error.

Test Results

The results of this test are shown graphically for better clarity in the three following sheets, arranged by levels of field strength.

Fig. 5 - DF Site Accuracy by Target Rotation - 3μV/m field strength

Fig. 6 - DF Site Accuracy by Target Rotation - 30μV/m field strength

Fig. 7 - DF Site Accuracy by Target Rotation - 1mV/m field strength

FIG. 5

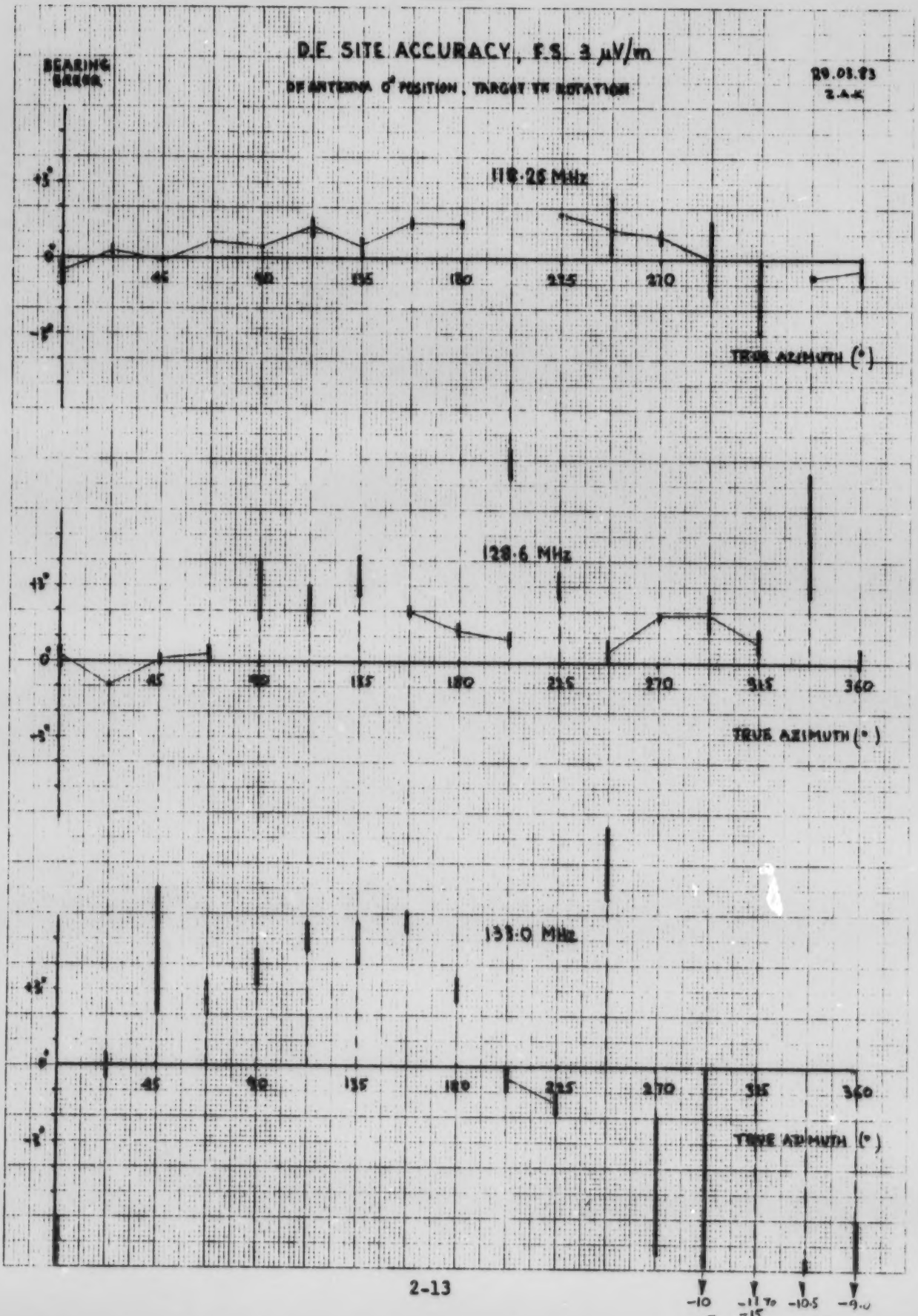

D.F. SITE ACCURACY, F.S. 3 μV/m
DF ANTENNA 0° POSITION, TARGET TX ROTATION
BEARING ERROR
29.03.83
Z.A.K.
118·25 MHz
+3°
0°
-3°
45
90
135
180
225
270
315
360
TRUE AZIMUTH (°)
128·6 MHz
+3°
0°
-3°
45
90
135
180
225
270
315
360
TRUE AZIMUTH (°)
133·0 MHz
+3°
0°
-3°
45
90
135
180
225
270
315
360
TRUE AZIMUTH (°)
-10
-11 TO -15
-10·5
-9·0

FIG. 6

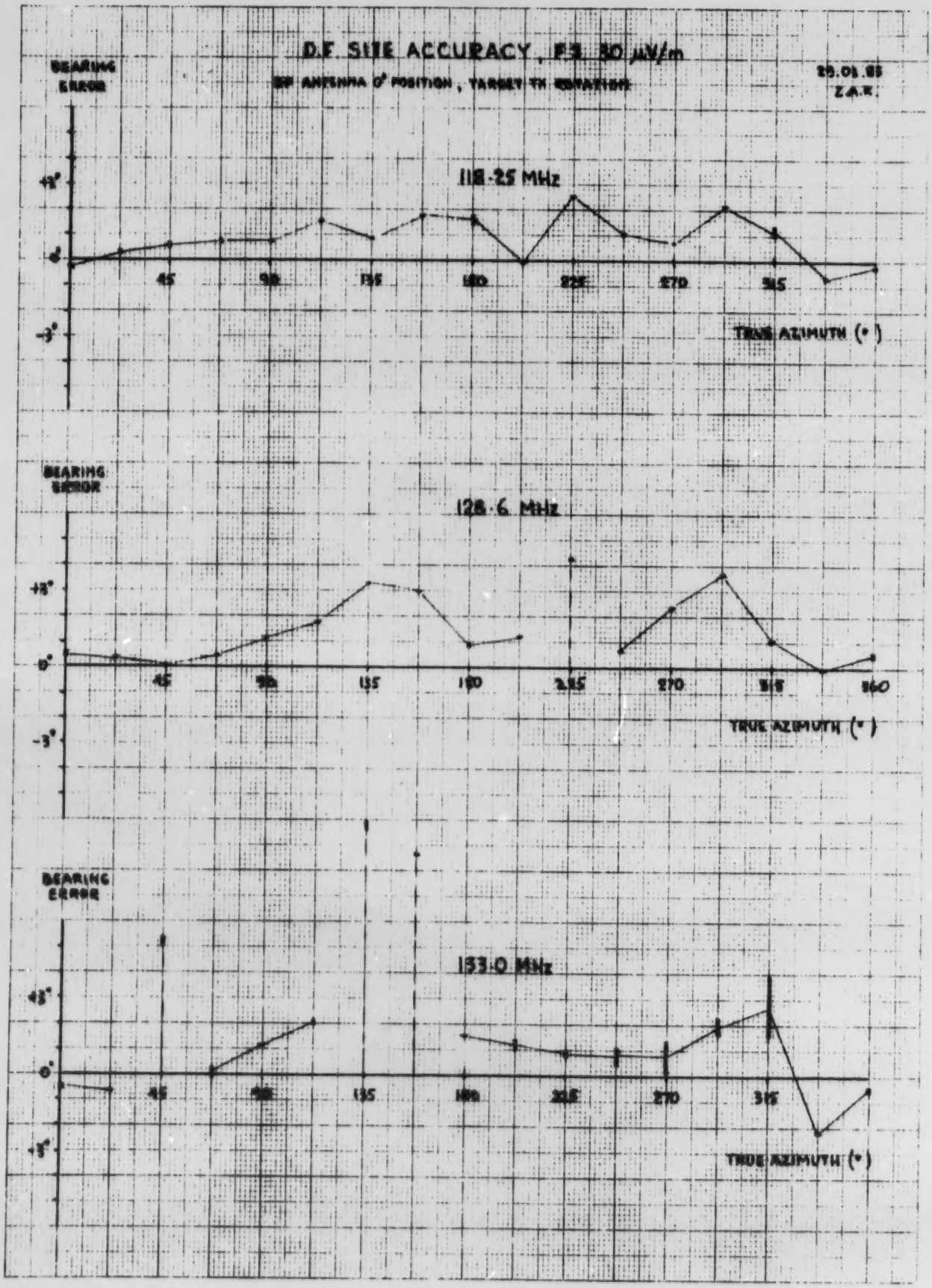
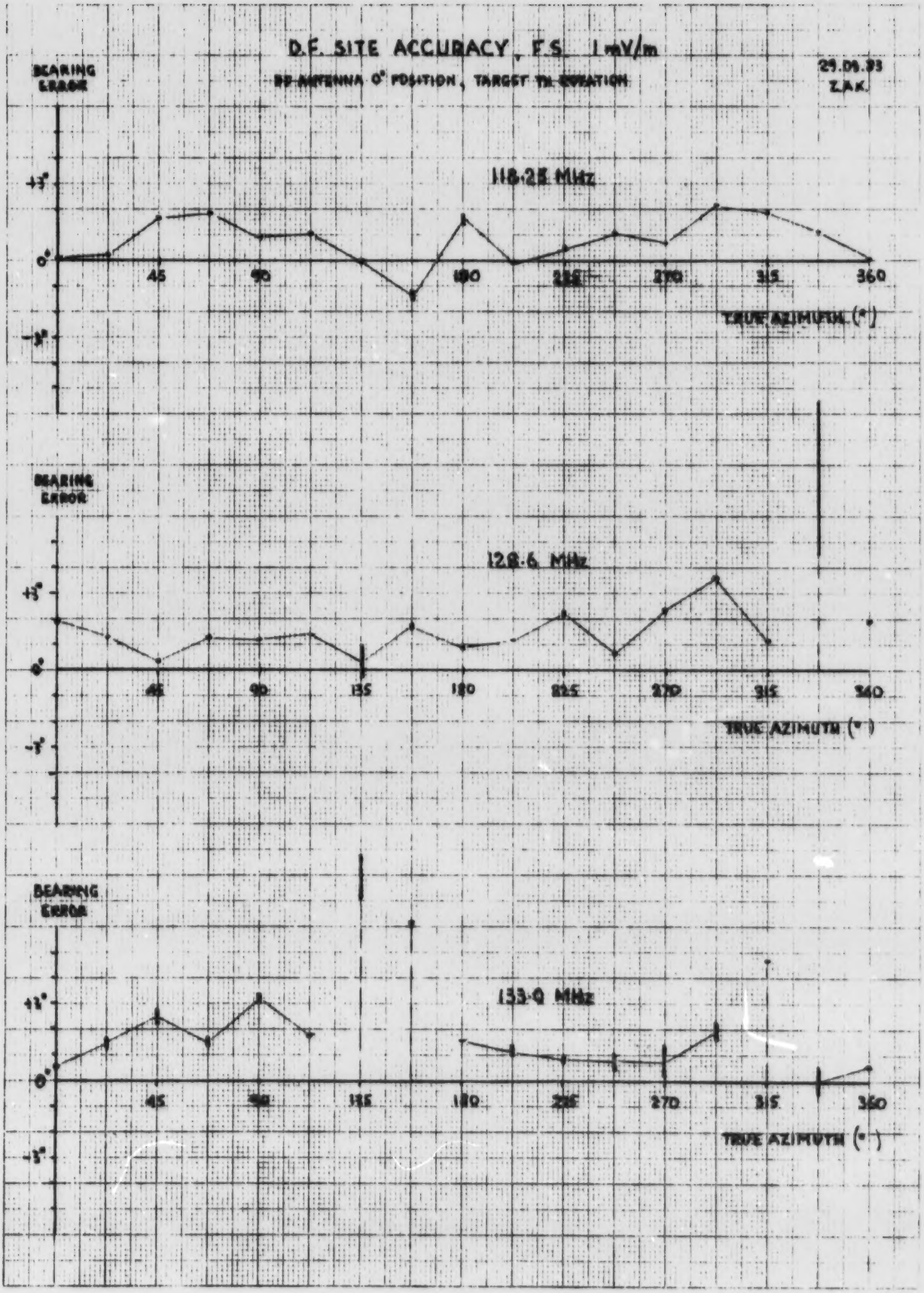

D.F SITE ACCURACY, FS 30 μV/m
BEARING ERROR
118·25 MHz
TRUE AZIMUTH (°)
128·6 MHz
133·0 MHz

FIG. 7


D.F. SITE ACCURACY, F.S. 1 mV/m
29.09.73
Z.A.K.
BEARING ERROR
118.25 MHz
+3°
0°
-3°
45
90
180
270
315
360
TRUE AZIMUTH (°)
BEARING ERROR
128.6 MHz
+3°
0°
-3°
45
90
135
180
225
270
315
360
TRUE AZIMUTH (°)
BEARING ERROR
133.9 MHz
+3°
0°
-3°
45
135
180
270
315
360
TRUE AZIMUTH (°)

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TEST NO. 4 - POLARIZATION ANGLE

Summary of Test Procedure

Bearing readings are taken first with the transmitter antenna vertical, and then inclined at 45° in a tangential plane to the DF array. The bearing change is noted as the result in change of polarization of the incoming wave. Tests were repeated at four different frequencies in the RF band, and at four different locations of the DF antenna, and with the transmitter in the 0° position of the calibration circle.

Specification

±1° approx.

Test Results (Field Strength 30μV/m)

Test Freq. MHz	Antenna Position	Bearing Vertical Min. °	Bearing Vertical Max. °	+45° Polarization Min. °	+45° Polarization Max. °	-45° Polarization Min. °	-45° Polarization Max. °
118.25	0.0°	0.6		1.1	1.2	359.2	359.3
128.6		0.4	0.6	0.3	0.4	359.6	359.7
128.7		0.3	1.1	359.7	0.7	358.1	359.3
133.0		359.5		359.5	359.6	1.7	2.4
118.25	90.0°	90.4		90.5	90.7	90.1	90.3
128.6		90.4		90.7	91.1	90.4	90.7
128.7		89.8	90.3	88.6	89.8	89.9	90.5
133.0		89.9	90.3	92.0	92.4	89.0	89.2
118.25	118.0°	180.5		180.3		180.2	180.8
128.6		179.2	179.3	180.2	180.3	179.1	179.2
128.7		179.1	179.4	178.4	179.0	178.5	179.0
133.0		181.3	181.4	179.4	179.5	181.6	182.0
118.25	270.0°	296.6		269.7	269.8	269.4	270.8
128.6		270.7	270.9	270.7	270.8	270.9	
128.7		270.3	270.8	265.8	269.7	269.3	270.8
133.0		272.5	272.3	267.1	273.4	270.1	270.5

Polarization Angle - Calculated Mean Errors

Test Freq. MHz	Antenna Position	Mean Error Vert. Polar. (ref.)	Mean Error +45°	Mean Error -45°	Max. Change °
118.25	0.0°	0.6	1.15	-0.75	-1.35
128.6		0.5	0.35	-0.35	-0.85
128.7		0.7	0.2	-1.3	-2.0
133.0		-0.5	-0.45	2.05	2.55
118.25	90.0°	0.4	0.6	0.2	±0.2
128.6		0.4	0.9	0.55	0.5
128.7		0.05	-0.8	0.2	-0.85
133.0		0.1	2.2	-0.9	2.1
118.25	180.0°	0.5	0.3	0.25	-0.25
128.6		-0.75	0.25	-0.85	1.0
128.7		-0.75	-1.25	-1.25	-0.6
133.0		1.35	-0.55	1.8	-1.9
118.25	270.0°	-0.4	-0.25	0.1	0.5
128.6		0.8	0.75	0.9	0.1
128.7		0.55	-2.55	0.05	-3.1
133.0		2.55	0.25	0.3	-2.3

Note

The additional readings at the test frequency of 128.7 MHz were taken to observe the effect of polarization with the presence of occasional interference.

TEST NO. 5 - ADJACENT CHANNEL BREAKTHROUGH

Summary of Test Procedure

The purpose of this test is to evaluate the interference caused by the presence of a strong signal in one of the adjacent frequency channels. The procedure is to have a weak signal transmitted on the wanted channel in an azimuth position of, say, 0° and a strong signal radiated from a second transmitter at 90° away from the first (say 270°). The frequency of the strong transmitter is then tuned in away from the wanted channel and bearing distortion or blanking out is then recorded against the frequency de-tuning. It will be noted that the bearing processor has a built-in automatic rejection of any readings that are out of order (as determined by a wide scatter or spread of deviations). Adjacent channel breakthrough, when observable, is producing such a scatter due to scan harmonic mixing and, therefore, causes the bearing reading to be blanked out.

Specification (Modified by the Company)

$\leq 1°$ error with adjacent channel signal up to 30 dB above wanted signal but not exceeding 3mV/m.

Test Results

	Tx No. 1 (Wanted)	Tx No. 2 (unwanted)	Bearing Readout ° Min.	Max.	Mean	Change ° from ref.
Antenna Position 0°						
Transm. Location	0°	270°				
Field Strength	30µV/m	1mV/m				
Test Frequency	128.6MHz	OFF	1.7	1.8	1.75	ref.
	128.6MHz	128.625	0.3	0.4	0.35	-1.4
	128.6MHz	128.620	359.4	0.0	359.7	-2.05
	128.6MHz	128.615	357.7	358.3	358.0	-3.75

TEST NO. 6 - TWO TEST SIGNALS IN THE SAME CHANNEL

Summary of Test Procedure

As distinct from Test No. 5, this test is to show the effect of interference of a second signal source tuned close to the same frequency as the wanted signal. This test was carried out directly after Test No. 5, and under the same conditions regarding location of transmitters, except that both targets were tuned to 118.25 MHz.

Specification

There is no contractual specification for this feature. It has been known from experience of other Doppler DF systems that the stronger of the two signals 'pulls-in' the bearing quite rapidly, a difference of 9-10 dB being usually sufficient for the changeover each way.

Test Results

Azimuth Deg.	Frequency MHz	Field Str. µV/m	dB above Tx.1	Bearing Reading ° Min.	Max.	Mean	Change ° from ref.
Transmitter No. 1							
247.5	118.25	30	Tx.1 OFF	0.3	0.6	0.45	ref.
Transmitter No. 2							
337.5	118.25	3	-20	0.5	0.9	0.65	+0.2
		10	-10	359.9	0.6	0.25	-0.2
		30	0	BLANK			BLANK
		100	+10	273.2	274.4	273.8	+2.6
		300	+20	271.9	272.2	272.05	+0.85
		1000	+30	271.9	272.2	272.05	+0.85
		30	Tx.2 OFF	271.1	271.3	271.2	ref.
additional check:		20	-4	351.0	BLANK		-

TEST NO. 7 - HIGH ANGLE ELEVATION (Simulated Test)

Summary of Test Procedure

The purpose of this test is to demonstrate the operation of the 'signal overhead' indicator lamp, and to estimate at which angle of elevation the lamp will come on or off. Instead of floating the target transmitter above the DF antenna, a position is found on the ground, near the antenna tower to give an equivalent angle of incidence in the vertical plane. The direct measurement of this angle is not very accurate because of re-radiation effects, both from the ground and the tower assembly. However, the equivalent angle of incidence can be computed from the reduction of amplitude of the phase detector waveform as observed on an oscilloscope.

Specification

Signal Overhead indication to operate at target elevation angles greater than 60° (±5°).

Test Results

The transmitter antenna was moved back and forth in the vicinity of the tower base until the 'overhead signal' lamp could be turned on and off. The Tx antenna position was noted and an approximate calculation was made of the angle of incidence. The amplitude of the phase waveform was also measured and compared with that from a distant location (61 m).

Both sets of results gave the indicator turn-on angle at approximately 55-65°.

COMMENTS ON TEST RESULTS

TEST NO. 1 - SYSTEM DF SENSITIVITY (CW MODE)

The system sensitivity is now well within the specification throughout the band, with the exception of the close vicinity of the 128.7 MHz spurious response, and the 128.7 MHz channel where outside interference was detected. The improvement is very considerable (better than 15 dB) as compared with the preliminary tests, thanks to cleaning up a fault in an RF amplifier.

TEST NO. 2 - DETUNING, CW MODE

Detuning of the carrier by ±6 kHz has negligible effect on bearing.

AM MODE, PERCENTAGE MODULATION

The effect of AM is negligible up to the 100% limit.

AM MODE WITH DETUNING

30% modulation of 1 kHz tone has negligible effect on bearing up to ±6 kHz off the centre frequency.

FM MODE WITH DETUNING

The effect of 3 kHz FM can be neglected for up to ±3 kHz detuning off the centre frequency. An assymmetry of the test results would indicate that the generator was misaligned.

EFFECT OF SIGNAL STRENGTH

The plot in Fig. 1 shows accep able errors up to a signal field strength level of 300 μV/m. A shift of +1° occurs above that limit and remains constant for higher levels. The RF AGC is suspected to be responsible for this condition and a re-alignment is recommended to remove the fault.

TEST NO. 3A - DF SYSTEM INSTRUMENTAL ACCURACY

The results of this test are very good at the low end of the RF band (118.25 MHz). The centre and high test frequencies display problems of erratic noise, giving pronounced bearing errors at certain angular positions of the DF antenna.

The noise was identified during the test as being generated by the phase detector when reading the ±180° limit of its characteristic. The noise detector incorporated in the circuit to correct for this problem was found to have insufficient bandwidth, consequently, in marginal conditions, it did not act to correct the detector mode. This type of error only shows at the higher test frequencies since the amplitude of the phase difference between the dipoles is increased as the input frequency increases. The exact position of the 'bad spots', or angles where the noise error is shown, is also dependent on the exact phase balance of the DF receiver channels which acts as a d.c. shift of the operating point of the phase detector. Hence, any drifts or adjustments of the phase balance have an influence on the distribution of the bearing errors caused by the °180° noise. The only sure remedy is to modify the phase detector circuit so as to cancel the effect of the ±180° noise.

The effect of the additional field strength error (see Test No. 2.5) is visible in the tests conducted with the field strength of 1 mV/m (Fig. 4).

TEST NO. 3B - DF SYSTEM SITE ACCURACY

Comments on Test 3A above also apply to this test. The occurrence of the bearing errors due to the noise is even more pronounced when the field site error is added on, as in this test. Bearing accuracy at the high end of the frequency band is particularly poor at the lowest level of field strength (3 μV/m).

TEST NO. 4 - POLARIZATION ANGLE

The effect of polarization of the incoming wave is negligible for the low and medium frequencies of the RF band. At the higher frequency end, the polarization error approaches 2.5° in one direction of rotation only. This may be due to the re-radiation from the test dipole support tripod which remains to be investigated.

TEST NO. 5 - ADJACENT CHANNEL BREAKTHROUGH

The system is capable of rejecting interference from an adjacent channel (25 kHz away) signal up to 30 dB above the wanted signal.

TEST NO. 6 - TWO TEST SIGNALS IN THE SAME CHANNEL

The 'pull-in' effect of a stronger signal is well demonstrated to be 10 dB or better.

TEST NO. 7 - HIGH ANGLE ELEVATION

The simulated test using the target antenna directly under the tower has shown satisfactorily the operation of the 'overhead pass' indicator. However, this type of test does not lend itself to measuring the bearing accuracy of elevated targets.

RECOMMENDATIONS

Results of the tests conducted on the DF System on March 28/29, 1983 show clearly that corrective action must be taken to cut out the excessive bearing errors due to the ±180° noise of the phase detector. A modification is required to the noise detector circuit to widen its bandwidth, so as to be able to act on the detector mode under marginal conditions. The DF accuracy curves should be repeated after the modification is made.

SUPPLEMENT TO FINAL TEST REPORT

PHASE DETECTOR AMBIGUITY

IMPROVEMENT INCORPORATED IN APRIL 1983

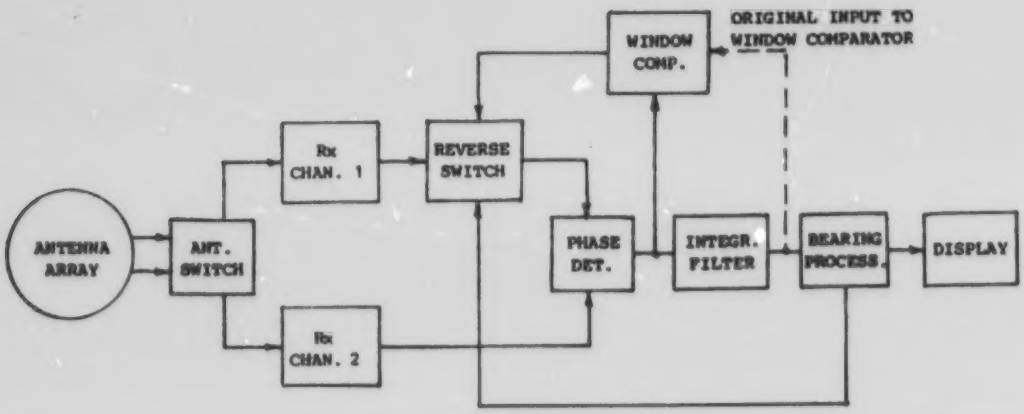
Problem

Discontinuity of phase detector characteristic at +180° or -180° resulting in randum bearing errors of up to 6° at certain azimuths at high frequency end.

Solution

By-passing the phase detector output filter in order to feed the discontinuity noise signal at full strength to the window comparator circuit so that it can activate reversal of the phase detector

Block Diagram



Results of Tests

No more ambiguity observed at any azimuth or frequency position.

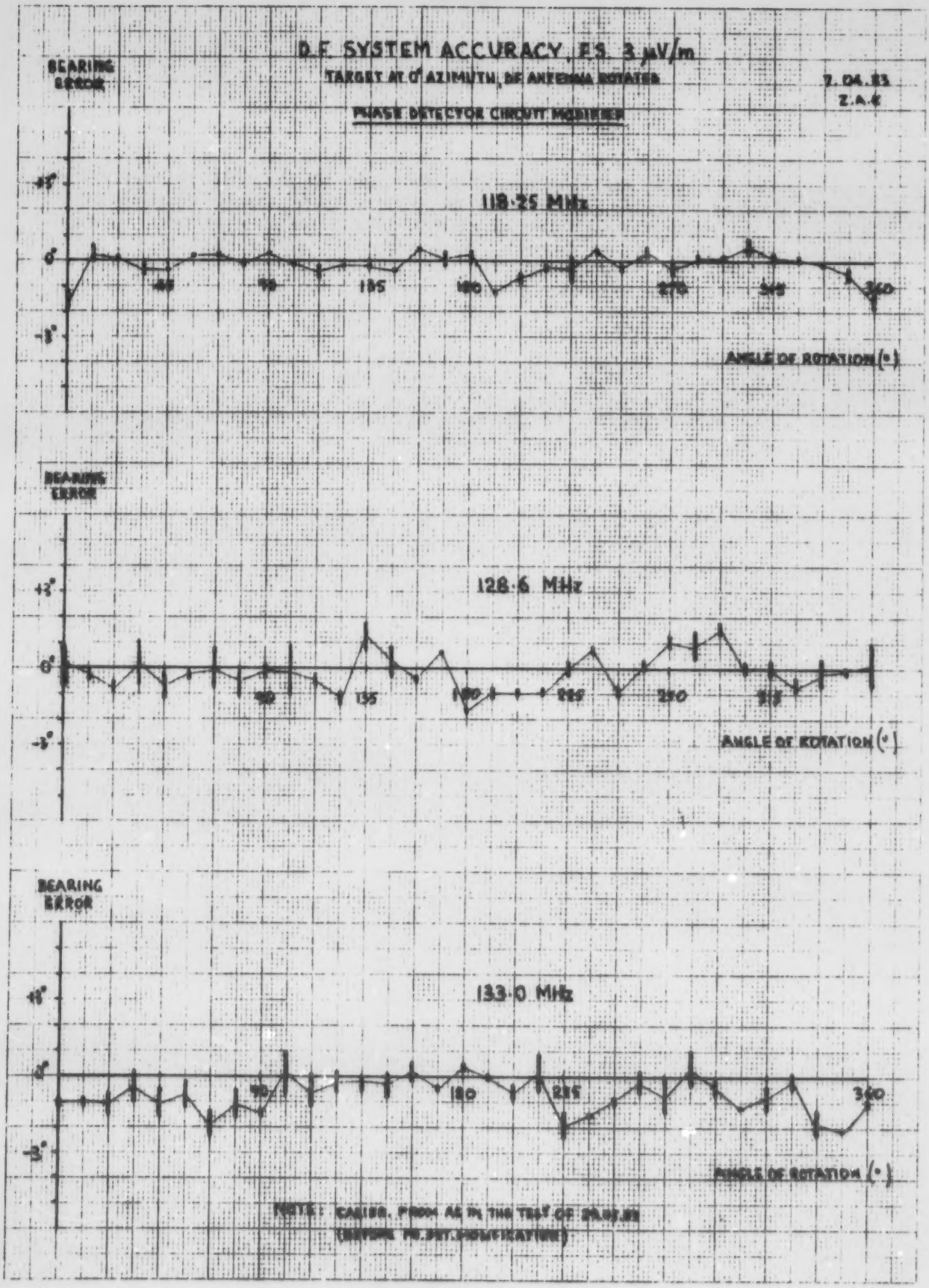
Reduction of scatter of bearing readouts for both high and low level of signal strength.

IMPROVED TEST RESULTS

The following three sets of graphs (Fig. 8, 9 and 10) show DF calibration test results obtained by rotating the antenna with a fixed target position of 0° azimuth. The readings were taken on April 7, 1983, after incorporation of a small circuit change in the phase detector which eliminates ambiguities in the close vicinity of the +180° and -180° limits. The nine graphs show bearing errors obtained at three input frequencies and at three different levels of field strength.

A comparison should be made with the corresponding graphs in Fig. 2, 3 and 4 of the Final Report which show the erratic results obtained during the end-of-March demonstration before the phase detector circuit was modified. Note the improvement of stability of the high-level bearings and the elimination of the random swings due to the discontinuity noise.

FIGURE 8



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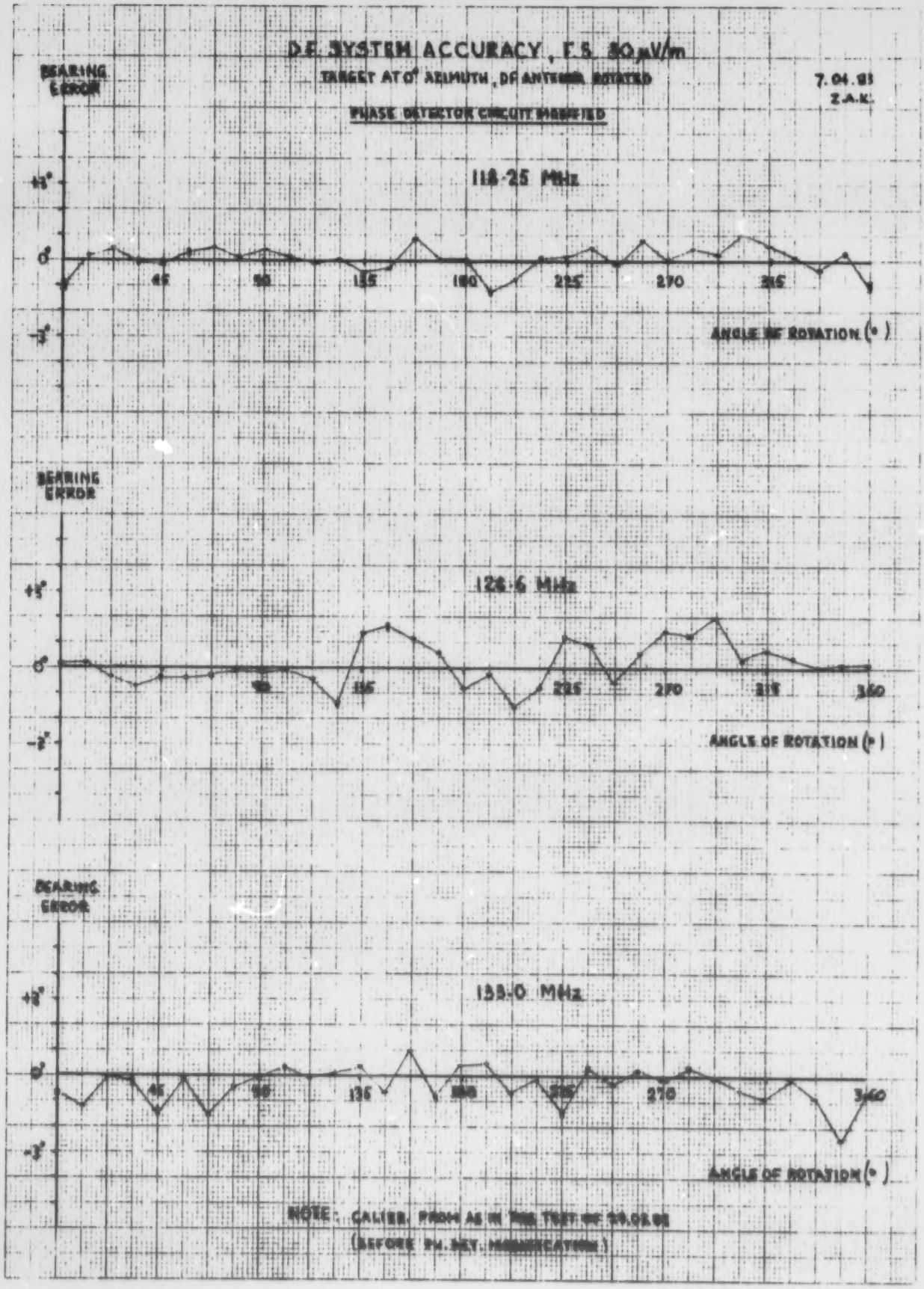
MADE IN U.K. TO THE CENTIMETER

FIGURE 9



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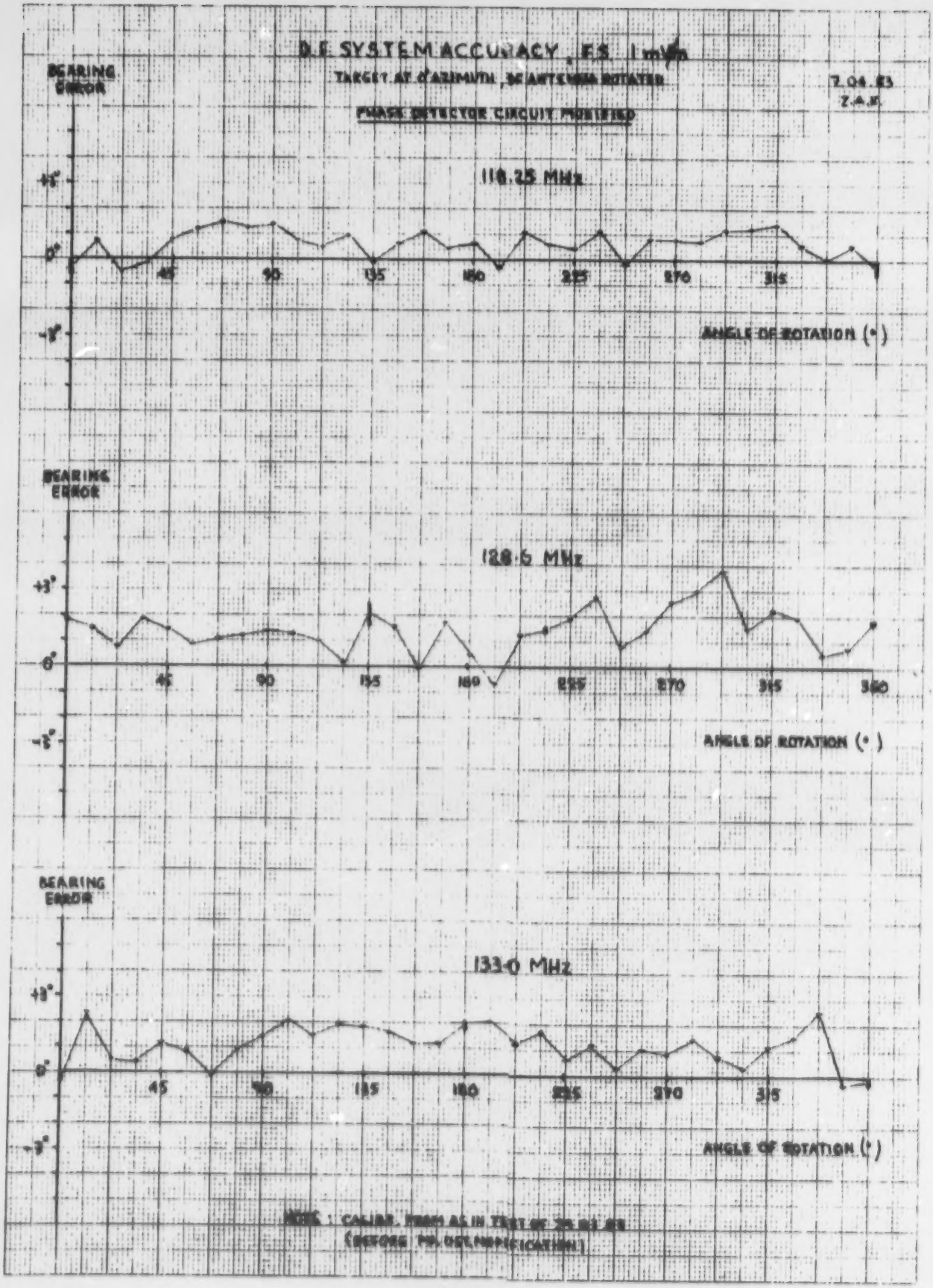
KEUFFEL & ESSER CO

FIGURE 10


D.F. SYSTEM ACCURACY, F.S. 1 mW/m
TARGET AT CONSTANT AZIMUTH, DF ANTENNA ROTATED
PHASE DETECTOR CIRCUIT MODIFIED
7.04.83
Z.A.F.
BEARING ERROR
118.25 MHz
+5°
0°
-5°
45
90
135
180
225
270
315
ANGLE OF ROTATION (°)
BEARING ERROR
128.6 MHz
+3°
0°
-3°
45
90
135
180
225
270
315
360
ANGLE OF ROTATION (°)
BEARING ERROR
133.0 MHz
+3°
0°
-3°
45
90
135
180
225
270
315
ANGLE OF ROTATION (°)
NOTE : CALIBR. FROM AS IN TEST OF 20.01.83
(BEFORE PRODUCTION)

APPENDIX 3

SYSTEM FIELD PERFORMANCE TEST PROCEDURE

SEPTEMBER 1982

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1.0 PRELIMINARY REQUIREMENTS

1.1 System Installation

The system field performance test procedures are to be performed on one complete set of system equipment as installed at an operational site.

Adjustment or calibration of the equipment is not permitted during the field performance tests. If any adjustment or calibration becomes necessary, all of the field performance test procedures must be repeated.

For the purposes of the tests, a calibration (azimuth) circle (see 3.0 and Figure 6-1) must be carefully marked out on the ground. Observe that the system North (0°) reference (preset adjustment) must agree with the 0° azimuth angle marked on the calibration circle. The method of determining the 0° azimuth point is subject to air-traffic control (ATC) regulations.

1.2 System Operating Conditions

Before starting the tests, a minimum 20-minute equipment warm-up period is required.

During the tests, the system is to be operated entirely from the front control/display panel on the Receiver Unit. For this purpose, the LOCAL/REMOTE switch toggle must be set to the LOCAL position.

2.0 ARRANGEMENT OF TEST PROCEDURES

The system field performance test procedures are arranged under Section 5.0 in test number order with title. The corresponding test log sheets, also in test number order, are grouped in Section 6.0. By performing the procedures in test number sequence, the handling and operation of test equipment is to some extent simplified. However, the procedure may be performed in any order.

A space on the test log sheet(s) is intended for the signatures of two competent witnesses of the test(s).

3.0 ILLUSTRATIONS

Figures 6-1 through 6-8 provide pictorial and other information of use during the test procedures. The illustrations are inserted immediately after the test log sheets.

4.0 TEST EQUIPMENT AND OTHER ITEMS REQUIRED

The following test equipment and other items are required in order to perform the system field performance test procedures. Where applicable, equivalent test equipment and items may be used.

Item	Qty	Description/Type/Model
1	2	Test transmitter: VHF band; peak continuous r-f output power _____; modulation modes CW, AM, FM; Model _____.
2	1	R-f power amplifier: VHF band; input power _____; output power _____ max; complete with accessories for use with Item 1.
3	2	Test dipole: VHF band; with cable and accessories for use with Item 1; complete with attachments for vertical mounting on Item 4.
4	2	Tripod: height _____cm; with suitable brackets for vertical mounting in Item 3; made by _____ (Type _____).
5	2	Portable power generator pack: 120 Vac, _____ VA; for use with Item 1; _____ Model.

Item	Qty	Description/Type/Model
6	1	Field strength meter: VHF band with calibrated antenna; range of measurement to cover 1μV/m through 100mV/m (approx.); for use with Item 1.
7	2	Binocular: wide angle 7 x 50; Model _____.
8	1	Survey map (of site area).
9	1	Helicopter: equipment to include radio altimeter and VHF transceiver for 128.7 MHz air-ground voice and df bearing.
10	1	Two-way radio; VHF band; for ground-to-air voice contact with the helicopter pilot on 128.7 MHz.
11	1	Plumb-weight (with 20-foot cord and attached 3-foot stick).
12	1	Sextant or similar elevation-angle device.

5.0 FIELD PERFORMANCE TESTS

Ensure that the mandatory preliminary requirements of Section 1.0 are in effect at all times.

Perform the following tests in test-number order (preferably). Enter all test results in the corresponding test log sheet(s) in Section 6.0. Obtain competent-witness signatures for the test log sheet(s) as applicable.

5.1 TEST NO. 1 SYSTEM DF SENSITIVITY (CW MODE)

5.1.1 Specification Limits

System sensitivity (vertical polarization):

$\leq 3\mu V/m$ for $\leq 3^{o}$ BEARING readout spread.

5.1.2 Test Equipment (Section 4.0)

Item 1	Test Transmitter	(1)
Item 3	Test dipole	(1)
Item 4	Tripod	(1)
Item 5	Power generator pack	(1)
Item 6	Field strength meter	(1)

5.1.3 Calibration Circle

Mark out a calibration circle according to Figure 6-1.

5.1.4 Obstruction Clearance for Test

Remove small metal objects, eg, wire, cans, boxes, tools, etc, to any location not less tha 200 feet distance from the antenna tower. Remove large metal objects, eg, vehicles, frames, ladders etc, to any location not less tha 400 feet distance from the antenna tower.

5.1.5 Test Procedure

NOTE

Figure 6-2 is a pictorial view (at ground level) of the general test set-up.

a Set up the test dipole at any selected angle on the calibration circle (Figure 6-1).

b Connect the test transmitter to the test dipole and power pack.

c Ensure that the transmitter and auxiliary equipment are positioned behind the test dipole and outmost from the calibration circle.

d Position the field strength meter under the antenna array and within the array circumference. Ensure that the meter antenna is properly aligned with the test antenna.

e Select test frequency 118.250 MHz on test transmitter and on the df system control panel.

f On the test transmitter, select modulation-mode CW.

g Set test transmitter output level to obtain 3μV/m reading on field strength meter. (NOTE: After Tx set-up, remove fsm from testing area.)

h On the df system control panel, set INTEGR SEC switch to '.8' position. Observe BEARING display readout and record the minimum reading and maximum reading obtained over at least 10 consecutive update readings. (NOTE: 'Update' means that the bearing readout changes slightly for successive bearing calculations made by the equipment.) Enter min/max readings in the appropriate spaces on TEST NO. 1 LOG sheet.

i Repeat steps e through g except set testing frequency to 128.7 MHz.

j Repeat steps e through g except set testing frequency to 133.0 MHz.

k Obtain signatures on test log sheet(s).

5.2 TEST NO. 2 EFFECT OF CONTROLLED VARIATIONS IN TEST SIGNAL OPERATING CONDITIONS

5.2.1 Purpose of Test

This test is intended to record the effect produced on the BEARING display readout due to controlled variations in the test signal operating conditions. The information obtained is to be recorded in the appropriate spaces of TEST NO. 2 LOG sheet. Observe that there are no specifications to be met. These test results are to be regarded as INFORMATION ONLY.

5.2.2 Test Equipment (Section 4.0)

Item 1	Test Transmitter	(1)
Item 2	R-f power amplifier	(1)
Item 3	Test Dipole	(1)
Item 4	Tripod	(1)
Item 5	Power generator pack	(1)
Item 6	Field strength meter	(1)

5.2.3 Calibration Circle

Mark out a calibration circle according to Figure 6-1.

5.2.4 Obstruction Clearance for Test

Remove small metal objects, eg, wire, cans, boxes, tools, etc, to any location not less than 200 distance from the antenna tower. Remove large metal objects, eg, vehicles, frames, ladders, etc, to any location not less than 400 feet distance from the antenna tower.

5.2.5 Test Procedure

NOTE

Figure 6-2 is a pictorial view (at ground level) of the general test set-up.

a Set up the test dipole on the calibration circle at any selected angle.

b Connect the test transmitter to the test dipole and the power pack.

c Ensure that the test transmitter and auxiliary equipment are positioned behind the test dipole and outermost from the calibration circle.

d Position the field strength meter under the antenna array and within the array circumference. Ensure that the meter antenna is properly aligned with the test antenna.

e On df system control panel, select frequency 127.0 MHz.

f On test transmitter, select frequency 127.0 MHz and modulation mode CW.

g Set test transmitter output level to obtain 10μV/m reading on field strength meter. (After use, remove the fsm from the testing area.)

h On the df system control panel, set INTEGR SEC switch to '.8' position. Observe BEARING display readout and record the minimum and maximum readings obtained over at least 10 consecutive update readings. (NOTE: 'Update' means that the bearing readout changes slightly for successive bearing calculations made by the equipment.) Enter the min/max readings in the appropriate spaces of TEST NO. 2 LOG sheet.

i Use the min/max readings recorded in step h above to calculate the average (arithmetic mean) value of each BEARING readout. Enter this value in the appropriate spaces on TEST NO. 2 LOG sheet.

j Repeat steps f through i above except set test transmitter frequency to 127.003 MHz (approx. +25ppm detune from channel centre frequency). DO NOT change the df system channel frequency of 127.0 MHz.

k Repeat steps f through i except set test transmitter frequency to 127.006 MHz (approx. +50ppm detune from channel centre frequency).

l Repeat steps f through i except set test transmitter frequency to 126.907 MHz (approx. -25ppm detune from channel centre frequency).

m Repeat steps f through i except set test transmitter frequency to 126.904 MHz (appro. -50ppm detune from channel centre frequency).

n Repeat steps f through m above except, on test transmitter, set modulation mode to AM, 1000 Hz tone modulation depth 30%.

o Repeat steps f through m except, on test transmitter, set modulation mode to FM, 1000 Hz tone, modulation deviation ±3kHz.

p Check that the test transmitter is set to 127.0 MHz, CW mode, and 10μV/m on field strength meter. (After Tx set up, remove fsm from testing area.) The df system must remain on channel frequency 127.0 MHz.

q Repeat steps h and i.

NOTE
In step r following, the larger field strength requirements will necessitate the connection of test equipment Item 2 (r-f power amplifier) to Item 1 (test transmitter).

r Repeat step p (with h and i) four times, except each time increment the test tramsmitter output by a nominal 20 dB step (ie, for each step in order, obtain an fsm reading of 100, 1000, 10,000, or 100,000 micro-volts per meter).

s Make one or more copies of blank Figure 6-3. Using the BEARING readout data obtained from steps p through r, plot this data on Figure 6-3. Attach one copy TEST NO. 2 LOG sheet(s).

t Obtain signatures on test log sheet.

5.3 TEST NO. 3 DF SYSTEM INSTALLATION ACCURACY (CW MODE)

NOTE

Test No. 3 involves an initial adjustment of the df system NORTH REFERENCE offset. For this purpose, the Angle and Averaging module (lower section of Receiver Unit) must be made accessible by means of a module extender.

5.3.1 Specification Limits

Df accuracy: ≤1.5° BEARING readout error with respect to true azimuth angle for specified test frequency 127.000 MHz. (Two other frequencies are used to obtain INFORMATION ONLY data.)

5.3.2 Test Equipment (Section 4.0)

Item 1	Test transmitter	(1)
Item 3	Test dipole	(1)
Item 4	Tripod	(1)
Item 5	Power generator pack	(1)
Item 6	Field strength meter	(1)
Item 7	Binoculars	(1)

5.3.3 Calibration Circle

Mark out a calibration circle according to Figure 6-1.

5.3.4 Obstruction Clearance for Test

Remove small metal objects, eg, wire, cans, boxes, tools, etc, to any location not less than 200 feet distance from the antenna tower. Remove large metal objects, eg, vehicles, frames, ladders, etc, to any location not less than 400 feet distance from the antenna tower. Additionally, for the test procedure (5.3.5), all cleared obstructions must be placed approximately 180° opposite the test dipole (ie, on the other side of the antenna array).

5.3.5 Test Procedure

NOTE

Figure 6-1 shows a typical df system installation offset of the antenna array centreline (0° mechanical) with respect to true azimuth (Ta)°. This offset will be electronically cancelled during steps a through l (which are performed once only). Therefore, the BEARING display readout error (plotted in Figure 6-4) is referenced to true azimuth angles, not array mechanical angles. (Figure 6-2 is a pictorial view of the general test set-up except for the distance required for the system installation offset adjustment.)

a Refer to Figure 6-1. Determine the 0° true azimuth line (marked 'N') according to Air Traffic Control (ATC) regulations. This 0° line should be extended to a distance of between 400 to 1000 feet in the 'N' direction with an angular accuracy of ±0.1°. The purpose of this line is to place the test dipole (with transmitter) on the line and as far distant from the antenna array as may be practicable.

b Set up the test dipole on the 'N' line and in the 'N' direction as far distant from the antenna array as is practicable. (This distance must not be less that 400 feet.)

c Connect the test transmitter to the test dipole and power pack.

d Ensure that the test transmitter and power pack are positioned behind the test dipole (with respect to testing direction).

e Position the field strength meter under the antenna array and within the array circumference. Ensure that the meter antenna is properly aligned with the test dipole.

f Select test frequency 127.0 MHz on the test transmitter and on the df system control panel.

g On the test transmitter, select modulation-mode CW.

h Set test transmitter output level to obtain 30μV/m on the field strength meter. (NOTE: After Tx set-up, remove fsm from testing area.)

i On the df system control panel, set INTEGR SEC switch to '.8' position.

j Observe the BEARING display readout. This readout will likely be a few degrees off 000.0 ± 0.1 (unless the system NORTH REFERENCE has already been adjusted and preset).

k To make the readout correction for step j, proceed as follows:

1 On the Angle and Averaging module, locate DIP switch S1. (NOTE: S1 consists of eight miniature rocker switches.)

2 While carefully observing the BEARING readout, operate the S1 switches, one-at-a-time, to obtain BEARING readout '000.0' 0.1. (NOTE: Obtain this readout over at least 10 consecutive readout update calculations made by the equipment.) If necessary, use the absolute magnitudes of the readout plus-and-minus excursion values (with respect to 000.0 to obtain a mean (average). This mean readout must equal 000.0 ± 0.1.

3 On TEST NO. 3 LOG sheet, make an entry (in the appropriate space) to record that the df system NORTH REFERENCE is correctly preset.

4 Move the test dipole, test transmitter, and power pack near to the calibration circle for further use.

NOTE

The test dipole set-up angles specified hereunder for the calibration circle are antenna array mechanical angles starting with 0° and proceeding through 22.5° intervals to cover 360°. These angles are slightly offset from the corresponding true azimuth angles (see Figure 6-1). However when a BEARING display readout error is specified, this error is referenced to a true azimuth angle (see TEST NO. 3 LOG sheet) as a result of steps a through k above.

l Obtain the help of an assistant to set-up the test dipole. Proceed as follows:

1 Stand on the calibration circle perimeter at antenna array mechanical angle 0°. Look toward the centre of the antenna array.

2 Move slowly left and right on the circle perimeter while at the same time observing (with the binoculars) the images of the nearest and farthest dipole pairs of the array. Align these images so that they are closely symmetrical with both your line-of-sight and the centre of the array.

3 Holding the binoculars steady while moving, refine the binoculars alignment so that the image of the far dipole pair in within and centred on the image of the near dipole pair. Hold this viewing angle steady during the test dipole set-up (4 below).

4 Have your assistant set up the test dipole (with tripod) on the calibration circle at the viewing angle that you are still holding (3 above). The test dipole must align vertically with the circle circumference and the viewing-angle centreline of the binoculars.

CAUTION

The test dipole position on the calibration circle is required to have an accuracy of $\pm 0.1^{o}$ (corresponding to ± 3 inches along the arc of the circle).

m Recheck the test dipole set-up accuracy.

n Connect the test transmitter to the test dipole and power pack.

o Ensure that the test transmitter and auxiliary equipment are positioned behind the test dipole and outermost from the calibration circle.

p Position the field strength meter under the antenna array and within the array circumference. Ensure that the meter antenna is properly aligned with the test dipole.

q Select test frequency 118.250 MHz on test transmitter and on the df system control panel.

r On the test transmitter, select modulation-mode CW.

s Set test transmitter output level to obtain 30μV/m reading on the field strength meter. (After Tx set-up, remove fsm from testing area.)

t On the df system control panel, set INTEGR SEC switch to '.8' position. Observe BEARING display readout and record the minimum reading and maximum reading obtained over at least 10 consecutive update readings. (NOTE: 'Update' means that the bearing readout changes slightly for successive bearing claculations made by the equipment.) Enter min/max readings in the appropriate spaces on TEST NO. 3 LOG sheet.

NOTE

For step u following, the min/max readout average (mean) is readily obtainable for all specified mechanical angles except 0°. For specified mechanical angle 0°, add 360 to the min/max sum before dividing by 2 to get the mean. If this quotient exceeds 360, subtract 360 to obtain the mean.

u Use the min/max readings recorded in step t above to calculate the average (arithmetic mean) value of the BEARING readout. Enter this value in the appropriate spaces on TEST NO. 3 LOG sheet.

v On TEST NO. 3 LOG sheet, enter the bearing error into the appropriate spaces. This error value, rounded-off to not more than two decimal places, is obtained from the following arithmetics:

$Ta^{o} - Bav^{o} = Be^{o}$
where
Ta^{o} = true azimuth angle reference.
Bav = average (mean) BEARING readout.
Be = bearing error referenced to true azimuth.

NOTE

The bearing error, Be, is the sum of the system installation and site errors. It should not inculde a system North reference error unless the preset system adjustment was incorrect.

w Repeat steps q through v, except set testing frequency to 127.0 MHz.

x Repeat steps q through v, except set testing frequency to 133.0 MHz.

y Repeat steps l through x 15 times except, for each repeat procedure, increment the true azimuth angle reference 22.5°. (This means that the total number of repetitive procedures will cover the 16 dipole pairs and 360° of the array.)

z Make three blank copies of Figure 6-4.

aa For each of the three testing frequencies, use a blank Figure 6-4 copy. On each copy, plot a graph of bearing error against true azimuth angle. (Use the test results recorded in steps 1 through y.)

ab Obtain signatures on test log sheet.

5.4 TEST NO. 4 BEARING READOUT CHANGE WITH RESPECT TO POLARIZATION ANGLE (CW MODE)

5.4.1 Specification Limits

Bearing readout error for a test dipole angle of 45° from the vertical in a plane tangential to the calibration circle (see 5.4.3).

$\leq 1°$ change from bearing readout made with the test antenna in the normal vertical position.

5.4.2 Test Equipment (Section 4.0)

Item 1	Test transmitter	(1)
Item 3	Test dipole	(1)
Item 4	Tripod	(1)
Item 5	Power generator pack	(1)
Item 6	Field strength meter	(1)

5.4.3 Calibration Circle

Mark out a calibration circle according to Figure 6-1.

5.4.4 Obstruction Clearance for Test

Remove small metal objects, eg, wire, cans, boxes, tools, etc, to any location not less than 200 feet distance from the antenna tower. Remove large metal objects, eg, vehicles, frames, ladders, etc, to any location not less than 400 feet distance from the antennna tower.

5.4.5 Test Procedure

NOTE

Figure 6-2 is a pictorial view (at ground level) of the general test set-up.

a Set up the test dipole on the calibration circle at mechanical angle 45°. The test dipole must be vertical.

b Connect the test transmitter to the test dipole and power pack.

c Ensure that the test transmitter and auxilary equipment are positioned behind the test dipole and outermost from the calibration circle.

d Position the field strength meter under the antenna array and within the array circumference. Ensure that the meter antenna is properly aligned with the test dipole.

e Select test frequency 118.250 MHz on the test transmitter and on the df system.

f ON the test transmitter, select modulation-mode CW.

g Set test transmitter output level to obtain 30μV/m reading on the field strength meter. (After Tx set-up, remove fsm from testing area.)

h On the df system control panel, set INTEGR SEC switch to '.8' position.

i Observe the test readout appearing on system control panel BEARING display and record this TEST NO. 4 LOG sheet (in the appropriate space).

j At the test dipole, mentally construct the vertical plane tangential to the calibration circle. Rotate the test dipole in this plane until it is at an angle 45° to the vertical. Maintain this test dipole angle.

k Repeat step i.

l Reset the test dipole to its normal vertical angle.

m Repeat steps e through l except set testing frequency to 128.750 MHz.

n Repeat steps e through l except set testing frequency to 133.0 MHz.

o Repeat steps a through n except, for each repeat procedure, increment the array angle by 90°. (This means that the total number of repetitive procedures will cover array angles 45°, 135°, 225°, and 315°.)

p Obtain signatures on test log sheet.

5.5 TEST NO. 5 ADJACENT CHANNEL BREAKTHROUGH EFFECT ON BEARING READOUT (CW MODE)

5.5.1 Specification Limits

Breakthrough effect due to a properly-centered 'unwanted' adjacent channel test signal displaced 90° from a 'wanted' test signal and within the following field strength constraints: unwanted signal 3mV/m and ≤50 dB above the level of the wanted signal.

The bearing readout change due to the above unwanted signal shall be limited as follows: ±1° with respect to the BEARING readout (reference) for the wanted signal when the unwanted signal is not present.

5.5.2 Test Equipment (Section 4.0)

Item 1	Test Transmitter	(2)
Item 2	R-f power amplifier	(1)
Item 3	Test dipole	(2)
Item 4	Tripod	(2)
Item 5	Power generator pack	(2)
Item 6	Field strength meter	(1)

5.5.3 Calibration Circle

Mark out a calibration circle according to Figure 6-1.

5.5.4 Obstruction Clearance for Test

Remove small metal objects, eg, wire, cans, boxes, tools, etc, to any location not less than 200 feet distance from the antenna tower. Remove large metal objects, eg, vehicles, frames, ladders, etc, to any location not less than 400 feet distance from the antenna tower.

5.5.5 Test Procedure

NOTE

Figure 6-5 is a pictorial view (overhead) of the general test set-up.

a Set up one test dipole (No. 1) on the calibration circle at any selected azimuth angle.

b Set up the other test dipole (No.2) on the circle at a position angularly displaced from dipole No. 1 by 90° in a clockwise direction (overhead view).

c Connect test transmitter No. 1 (without r-f power amplifier) to test dipole No. 1 and to its power pack.

d Connect test transmitter No. 2 (with r-f power amplifier to test dipole No. 2 and to its power pack. DO NOT switch-on this transmitter until it is required.

e Ensure that the test transmitters and auxiliary equipment are positioned behind the test dipoles and outermost from the calibration circle.

f Position the field strength meter under the antenna array and within the array circumference. Ensure that the meter antenna is properly aligned with test dipole No. 1.

g On test transmitter No. 1, select test frequency 128.7 MHz and modulation-mode CW. Select df system frequency 128.7 MHz.

h Set test transmitter No. 1 output level to obtain 10μV/m on the field strength meter. (NOTE: After Tx set-up, remove fsm from testing area.)

i On the df system control panel, set INTEGR SEC switch to '.8' position. Record the BEARING display readout on TEST NO. 5 LOG sheet.

j Repeat step f except align the fsm antenna with test dipole No. 2.

k On test transmitter No. 2, select test frequency 128.725 MHz (adjacent channel) and modulation mode CW.

l Set test transmitter No. 2 (with r-f power amplifier) output level to obtain 3mV/m (50 dB above test transmitter No. 1 level) on the field strength meter. (Note: After Tx set-up, remove fsm from testing area.)

m Record the BEARING display readout on TEST NO. 5 LOG sheet.

NOTE

Steps n and o following are not tests. They are intended only for observation of the system behaviour under adverse conditions.

n Repeat steps k through m except set test transmitter No. 2 (only) test frequency to 128.720 MHz.

o Repeat steps k through m except set test transmitter No. 2 (only) test frequency to 128.715 MHz.

p Obtain signatures on test log sheet.

5.6 TEST NO. 6 EFFECT OF TWO TEST SIGNALS RECEIVED IN THE SAME CHANNEL AND ANGULARLY DISPLACED BY 90° (CW MODE)

5.6.1 Purpose of Test

This test is intended to record the effect produced on the BEARING display readout when two test signals of identical frequency and variable field strengths are received in one selected channel. The information obtained is to be recorded in the appropriate spaces of TEST NO. 6 LOG sheet. Observe that there are no specifications to be met. These test results are to be regarded as INFORMATION ONLY.

5.6.2 Test Equipment (Section 4.0)

Item 1	Test transmitter	(2)
Item 2	R-f power amplifier	(1)
Item 3	Test dipole	(2)
Item 4	Tripod	(2)
Item 5	Power generator pack	(2)
Item 6	Field strength meter	(1)

5.6.3 Calibration Circle

Mark out a calibration circle according to Figure 6-1.

5.6.4 Obstruction Clearance for Test

Remove small metal objects, eg, wire, cans, boxes, tools, etc, to any location not less than 200 feet disatance from the antenna tower. Remove large metal objects, eg, vehicles, frames, ladders, etc, to any location not less than 400 feet distance from the antenna tower.

5.6.5 Test Procedure

NOTE

Figure 6-5 is a pictorial view (overhead) of the general test set-up.

a Set up one test dipole (No. 1) on the calibration circle at any selected array angle.

b Set up the other test dipole (No. 2) on the circle at a position angularly displaced from dipole No. 1 by 90° in a clockwise direction (overhead view).

c Connect test transmitter No. 1 (without r-f power amplifier) to test dipole No. 1 and to its power pack.

d Connect test transmitter No. 2 (with r-f power amplifier) to test dipole No. 2 and to its power pack. DO NOT switch-on this transmitter until it is required.

e Ensure that the test transmitter and auxiliary equipment are positioned behind the test dipoles and outermost from the calibration circle.

f Position the field strength meter under the antenna array and within the array circumference. Ensure that the meter antenna is properly aligned with test dipole No. 1.

g On test transmitter No. 1, select test frequency 127.0 MHz and modulation mode CW. Select df system frequency 127.0 MHz.

h Set test transmitter No. 1 output level to obtain 30μV/m reading on the field strength meter. This output is to remain constant throughout the test. (NOTE: After Tx set-up, remove fsm from testing area.)

i On the df system control panel, set INTEGR SEC switch to '.8' position. Record the BEARING display readout on TEST NO. 6 LOG sheet.

j Repeat step f except align the fsm antenna with test dipole No. 2.

k On test transmitter No. 2, select test frequency 127.0 MHz and modulation mode CW.

l Set test transmitter No. 2 output level to obtain 3μV/m reading on the field strength meter. (NOTE: After Tx set-up, remove fsm from testing area.)

m Repeat step i above.

NOTE

In step n following, the larger field strength requirements will necessitate the connection of test equipment Item 2 (r-f amplifier) to Item 1 (test transmitter).

n Repeat steps l and i (in that order) six times, except each time increment the test transmitter No. 2 output by a nominal 10 dB steps (ie, for each step in order, obtain an fsm reading or 10, 30, 100, 300, 1000, or 3000 micro-volts per meter).

o Make one or more copies of blank Figure 6-6. On each copy, plot the absolute BEARING readouts from the recorded test data. Attach one copy to TEST NO. 6 LOG sheet(s).

NOTE

Step o above should show (on Figure 6-6) a 'crossover' of the absolute BEARING readout from the Tx1 bearing to the Tx2 bearing. The following steps are intended to indicate the 'slope' or steepness of this crossover.

p Switch-off test transmitter No. 2. (This will allow the df system to 're-capture' the test transmitter No. 1 bearing.)

q Set test transmitter No. 2 output level to obtain 22μV/m on the field strength meter. (NOTE: After Tx set-up, remove fsm from testing area.)

r Repeat step i above.

s Repeat steps q and i above (in that order) eleven times, each time incrementing the test transmitter No. 2 output by a nominal one dB step (ie, for each step in order, obtain an fsm reading of 26, 30, 34, 38, 42, 46, 50, 54, 58, 62, or 66 micro-volts per meter).

t Make one or more copies of blank Figure 6-7. On each copy, plot the relative BEARING readouts from the recorded test data. Attach one copy to TEST NO. 6 LOG sheet(s).

u Obtain signatures on test log sheet.

5.7 TEST NO. 7 BEARING READOUT CHANGE FOR HIGH-ANGLE ELEVATION WITH OVERHEAD-PASS INDICATION

5.7.1 Specification Limits

Referred to a df system BEARING display readout obtained for a minimum elevation angle (effectively 0°), any change in the BEARING readout for an elevation angle of 45° (approx.) shall not exceed ±1°. The signal source shall be carried in a helicopter hovering directly over one landmark approximately 1 kilometer distance from the antenna site.

The helicopter shall then rise vertically (and directly over the landmark) to obtain the height and instant at which the df system OVERHEAD PASS light (blue) starts flashing. The start instant must occur within the elevation-angle limits 60 ±5°. The site OVERHEAD PASS elevation angle shall be calculated (from the height value) and recorded.

Finally, the helicopter shall hover directly over the specified landmark at an elevation angle of 60° (approx.). The df BEARING readout, if it is obtainable for this elevation, shall be observed and referred to the reference elevation (0°) readout. The amount of change, if any, shall be recorded, but no limits shall be specified.

5.7.2 Test Equipment (Section 4.0)

Item 7	Binoculars	(1)
Item 8	Survey map	
Item 9	Helicopter (with specified equip.)	(1)
Item 10	Two-way radio	(1)
Item 11	Plumb-weight and line (with stick)	(1)
Item 12	Elevation angle-measuring device	(1)

5.7.3 Calibration Circle

A calibration circle is not required for this test provided that all other field performance tests have been completed successfully.

5.7.4 Obstruction Clearance for Test

Remove small metal objects, eg, wire, cans, boxes, tools, etc, to any location not less than 200 feet distance from the antenna tower. Remove large metal objects, eg, vehicles, frames, ladders, etc, to any location not less than 400 feet distance from the antenna tower.

5.7.5 Test Procedure

NOTE

Figure 6-8 is a pictorial view of the general test set-up.

a In consultation with the helicopter pilot, use the survey map to find a suitable landmark visible from both ground and air. This landmark should be situated at an approximate distance of 1 kilometer from the antenna site. (NOTE: The heights given hereunder are based on a 1 kilometer distance. If necessary, adjust the procedure base-distance and heights to agree with the actual conditions of the site and landmark.)

b Attach the plumb-weight to the line (with stick). Insert the stick into the antenna tower lattice at a height that allows the weight to just clear the ground. (NOTE: Ensure that there is no obstruction to a line-of-sight extending from the plumbline to the specified landmark.)

c Ensure that ground-to-air and air-to-ground communication will both be on 128.7 MHz. This frequency must also be selected on the df system control panel.

d Request the helicopter pilot to hover directly over the specified landmark at minimum height (eg, 100 feet radio altimeter).

e Obtain df BEARING readout and enter into the appropriate space on TEST NO. 7 LOG sheet.

f Request helicopter to rise vertically and hover directly over landmark at 3200 feet (radio altimeter). This height represents an elevation angle of 45° (approx.). Check that the helicopter is aligned over the landmark with respect to the line-of-site from the antenna plumb-line.

g Record the df system BEARING display readout (for step f) on TEST NO. 7 LOG sheet.

h Request helicopter to rise slowly while maintaining vertical position over the landmark. Alert the pilot to your forthcoming request for radio altimeter height in step i following.

i While the helicopter is rising (step h), observe the blue OVERHEAD PASS light indicator on the df system control panel. At the instant that the light starts flashing, request helicopter height (radio altimeter). Record the height on TEST NO. 7 LOG sheet together with the BEARING readout for this height.

j Request the helicopter pilot to continue rising and then hover directly over the landmark at 5800 feet (radio altimeter). This height represents an elevation angle of 60° (approx.). Check the line-of-sight.

k Obtain the BEARING readout (if it can be obtained) for step j and record on TEST NO. 7 LOG sheet.

l Inform the helicopter pilot that the tests have been completed.

m From step i, above, calculate the minimum elevation angle for the start of the OVERHEAD PASS flashing indication. Enter this on the test log sheet.

n Obtain signatures on the test log sheet.

6.0 TEST LOG SHEETS FOR QUASI-DOPPLER DF SYSTEM XXXX FIELD PERFORMANCE TESTS

This section contains the test log sheets for the field performance test procedures described in Sections 1.0 through 4.0 and detailed in Section 5.0.

In Section 5.0, each test procedure was given a test number (eg, Test No. 1). Likewise, the associated test log sheets herewith are each identified by a corresponding test log numbers (eg, Test No. 1 Log).

Each completed test log must be certified by the signatures of two competent witnesses together with the location and date of the test. When all the test logs have been certified, they provide a collective acceptance of the df system field performance test results.

6.1 TEST NO. 1 LOG SYSTEM DF SENSITIVITY (CW MODE)

a References

Section 1.0 through 4.0 (general)
Section 5.0 (field performance tests)
Sub-section 5.1 (Test No. 1, requirements and procedure)

b Test Results (field strength 3μV/m)

Test Freq. (MHz)	Bearing Readout ° Min	Max	Bearing Spread ° >3	≤3
118.250	---	---	---	---
128.700	---	---	---	---
133.000	---	---	---	---

c Certification

The above test results (b) are within the specified limits: ≤3μV/m for ≤3° BEARING readout spread.

Signed - Signed -

_____ _____

Location: _____ Date: _____

6.2 TEST NO. 2 LOG EFFECT OF CONTROLLED VARIATIONS IN TEST SIGNAL OPERATING CONDITIONS

a References

Section 1.0 through 4.0 (general)
Section 5.0 (field performance tests)
Sub-section 5.2 (Test No. 2, requirements and procedure)

b Test Results

1. CW Mode Data (field strength 10μV/m)

Test Freq. (MHz)	Bear. Read.° Min.	Max.	Read. Mean°	±Change° (from Ref.)
127.000	---	---	___(Ref)	XXXX
127.030	---	---	---	----
127.060	---	---	---	----
126.970	---	---	---	----
126.940	---	---	---	----

2. AM* Mode Data (field strength 10μV/m)

Test Freq. (MHz)	Bear. Read.° Min.	Max.	Read. Mean°	±Change° (from Ref.)
127.000	---	---	___(Ref)	XXXX
127.030	---	---	---	----
127.060	---	---	---	----
126.970	---	---	---	----
126.940	---	---	---	----

* 1000Hz tone, depth 30%.

3. FM* Mode Data (field strength 10 μV/m)

Test Freq. (MHz)	Bear. Read.° Min.	Max.	Read. Mean°	±Change° (from Ref.)
127.000	---	---	___(Ref)	XXXX
127.030	---	---	---	----
127.060	---	---	---	----
126.970	---	---	---	----
126.940	---	---	---	----

* 1000Hz tone, deviation ±3 kHz.

4. Strong Signal Data (127.000 MHz CW mode)

Test Sig. Strength	Bear. Read.° Min.	Max.	Read. Mean°	±Change° (from Ref.)
10 V/m	---	---	___(Ref)	XXXX
100 V/m	---	---	---	----
1mV/m	---	---	---	----
10mV/m	---	---	---	----
100mV/m	---	---	---	----

5. Plot of Strong Signal Data (b, 4. above)

Attach one copy of Figure 6-3 to TEST NO. 1 LOG sheet(s).

c Certification

The above test results b are recorded for information only.

Signed -

_____

Signed -

_____

Location: _____

Date: _____

TEST NO. 3 LOG DF SYSTEM INSTALLATION ACCURACY (CW MODE)

a References

Section 1.0 through 4.0 (general)
Section 5.0 (field performance tests)
Sub-section 5.3 (Test No. 3, requirements and procedure)

b Test Results (field strength 30μV/m)

1. DF System North-Reference Preset Adjustment

Correctly Preset	
Yes	No
---	---

2. Numerical Data

NOTE

The specified test frequency is 127.000 MHz only. All other data is for information only.

Test Freq. (MHz)	True Az. (Ta)°	Bear. Read.° Min.	Max.	Read. Mean°	±Error° of Mean Referred to Ta
118.250	0	---	---	----	----
127.000	0	---	---	----	----
133.000	0	---	---	----	----
118.250	22.5	---	---	----	----
127.000	22.5	---	---	----	----
133.000	22.5	---	---	----	----
118.250	45.0	---	---	----	----

Test Freq. (MHz)	True Az. (Ta)°	Bear. Read.° Min.	Max.	Read. Mean°	±Error° of Mean Referred to Ta
127.000	45.0	---	---	----	----
133.000	45.0	---	---	----	----
118.250	67.5	---	---	----	----
127.000	67.5	---	---	----	----
133.000	67.5	---	---	----	----
118.250	90.0	---	---	----	----
127.000	90.0	---	---	----	----
133.000	90.0	---	---	----	----
118.250	112.5	---	---	----	----
127.000	112.5	---	---	----	----
133.000	112.5	---	---	----	----
118.250	135.0	---	---	----	----
127.000	135.0	---	---	----	----
133.000	135.0	---	---	----	----
118.250	157.5	---	---	----	----
127.000	157.5	---	---	----	----
133.000	157.5	---	---	----	----
118.250	180.0	---	---	----	----
127.000	180.0	---	---	----	----
133.000	180.0	---	---	----	----
118.250	202.5	---	---	----	----
127.000	202.5	---	---	----	----
133.000	202.5	---	---	----	----

Test Freq. (MHz)	True Az. (Ta)°	Bear. Read.° Min.	Max.	Read. Mean°	±Error° of Mean Referred to Ta
118.250	225.0	---	---	----	----
127.000	225.0	---	---	----	----
133.000	225.0	---	---	----	----
118.250	247.5	---	---	----	----
127.000	247.5	---	---	----	----
133.000	247.5	---	---	----	----
118.250	270.0	---	---	----	----
127.000	270.0	---	---	----	----
133.000	270.0	---	---	----	----
118.250	292.5	---	---	----	----
127.000	292.5	---	---	----	----
133.000	292.5	---	---	----	----
118.250	315.0	---	---	----	----
127.000	315.0	---	---	----	----
133.000	315.0	---	---	----	----
118.250	337.5	---	---	----	----
127.000	337.5	---	---	----	----
133.000	337.5	---	---	----	----

3. Graph Plot of Numerical Data

Attach three copies of Figure 6-4 (graph) showing bearing readout error through 360° for operating frequencies 118.250 MHz, 127.000 MHz, and 133.000 MHz.

c Certification

With the df system North-reference correctly preset, the above test results (b, 2) are within the specified limits: ≤ 1.5 degrees BEARING (mean) readout error referred to true azimuth degrees for specified test frequency 127.000 MHz only.

Signed -

_____

Signed -

_____

Location: _____

Date: _____

4 TEST NO.4 BEARING READOUT CHANGE WITH RESPECT TO POLARIZATION ANGLE (CW MODE)

a References

Section 1.0 through 4.0 (general)
Section 5.0 (field performance tests)
Sub-section 5.4 (Test No. 4, requirements and procedures)

b Test Results (field strength 30μV/m)

Test Freq. (MHz)	Array Angle °	Bearing Readout °		±Change ° from Vert. Read.
		Vert. Polar.	45° Polar.	
118.250	45.0	----------	----------	----------
128.700	45.0	----------	----------	----------
133.000	45.0	----------	----------	----------
118.250	135.0	----------	----------	----------
128.700	135.0	----------	----------	----------
133.000	135.0	----------	----------	----------
118.250	225.0	----------	----------	----------
128.700	225.0	----------	----------	----------
133.000	225.0	----------	----------	----------
118.250	315.0	----------	----------	----------
128.700	315.0	----------	----------	----------
133.000	315.0	----------	----------	----------

c Certification

The above test results (b) are within the specified limits: $\leq 1^{o}$ change in bearing readout for 45^{o} polarized test dipole referred to bearing readout for vertical polarized test dipole.

Signed -

_____

Signed -

_____

Location: _____

Date: _____

6.5 TEST NO. 5 LOG ADJACENT CHANNEL BREAK-THROUGH EFFECT ON BEARING READOUT (CW MODE)

a **References**

Section 1.0 through 4.0 (general)
Section 5.0 (field performance tests)
Sub-section 5.5 (Test No. 5, requirements and procedures)

b **Test Results** (field strength: Tx No.1, 10μV/m; Tx No. 2, 3mV/m)

Test Freq. (MHz) (Tx No. 1) *	Test Freq. (MHz) (Tx No. 2) **	Bearing Readout °	±Change ° from Ref
128.700	OFF	---------	XXXX
128.700	128.725	---------	----
128.700	128.720	---------	---- ***
128.700	128.715	---------	---- ***

* Wanted test signal.
** Unwanted adjacent channel test signal 90° displaced from wanted signal.
*** Not a test result. INFORMATION ONLY.

c Certification

Refer to b above. With repect to a clear 'wanted' test signal bearing readout (reference), any readout change does not exceed ±1° when due to the presence of a properly-centered adjacent channel 'unwanted' test signal (*** entries excepted) under the specified test signal conditions.

Signed -

_____

Signed -

_____

Location: _____

Date: _____

6.6 TEST NO. 6 LOG EFFECT OF TWO TEST SIGNALS RECEIVED IN THE SAME CHANNEL AND ANGULARLY DISPLACED BY 90° (CW MODE)

a References

Section 1.0 through 4.0 (general)
Section 5.0 (field performance tests)
Sub-section 5.5 (Test No. 5, requirements and procedures)

b Test Results

1. Bearing Readout Crossover Data

Tx No. 1 μV/m	Tx No. 2 μV/m	Bearing Readout °	±Change ° from Ref.
30	OFF	___(Ref.)	XXXX
30	3	----	----
30	10	----	----
30	30	----	----
30	100	----	----
30	300	----	----
30	1000	----	----
30	3000	----	----

2. Bearing Readout Crossover Slope Data

Tx No. 1 μV/m	Tx No. 2 μV/m	Bearing Readout °	±Change ° from Ref.
30	OFF	___(Ref.)	XXXX
30	22	----	----
30	26	----	----

Tx No. 1 μV/m	Tx No. 2 μV/m	Bearing Readout °	±Change ° from Ref.
30	30	----	----
30	34	----	----
30	38	----	----
30	42	----	----
30	46	----	----
30	50	----	----
30	54	----	----
30	58	----	----
30	62	----	----
30	66	----	----

3. Graph Plots of Numerical Data

Attach one copy each of Figure 6-6 and Figure 6-7 showing bearing readout crossover and slope data respectively.

c Certification

The above test results (b) are recorded for information only.

Signed -

_____

Signed -

_____

Location: _____

Date: _____

6.7 TEST NO. 7 LOG BEARING READ CHANGE FOR HIGH-ANGLE ELEVATION WITH OVERHEAD-PASS INDICATION

a References

Section 1.0 through 4.0 (general)
Section 5.0 (field performance tests)
Sub-section 5.5 (Test No. 5, requirements and procedures)

b Test Results

Elev. °	Elev. (ft)	Bearing Readout °	±Change from Ref.
0	100	__(Ref)	XXXX
45	3200	---	----
-----*	----**	---***	----***
60	5800	---***	----***

* OVERHEAD PASS minimum elevation angle (calculated) for start of flashing indication.
** Obtained by helicopter for *.
*** Not a test. INFORMATION ONLY.

c Certification

For 45° elevation only, the bearing readout change referred to the reference readout does not exceed ±1°. The OVERHEAD PASS light starts flashing within elevation angle limits 60 ±5°.

Signed -

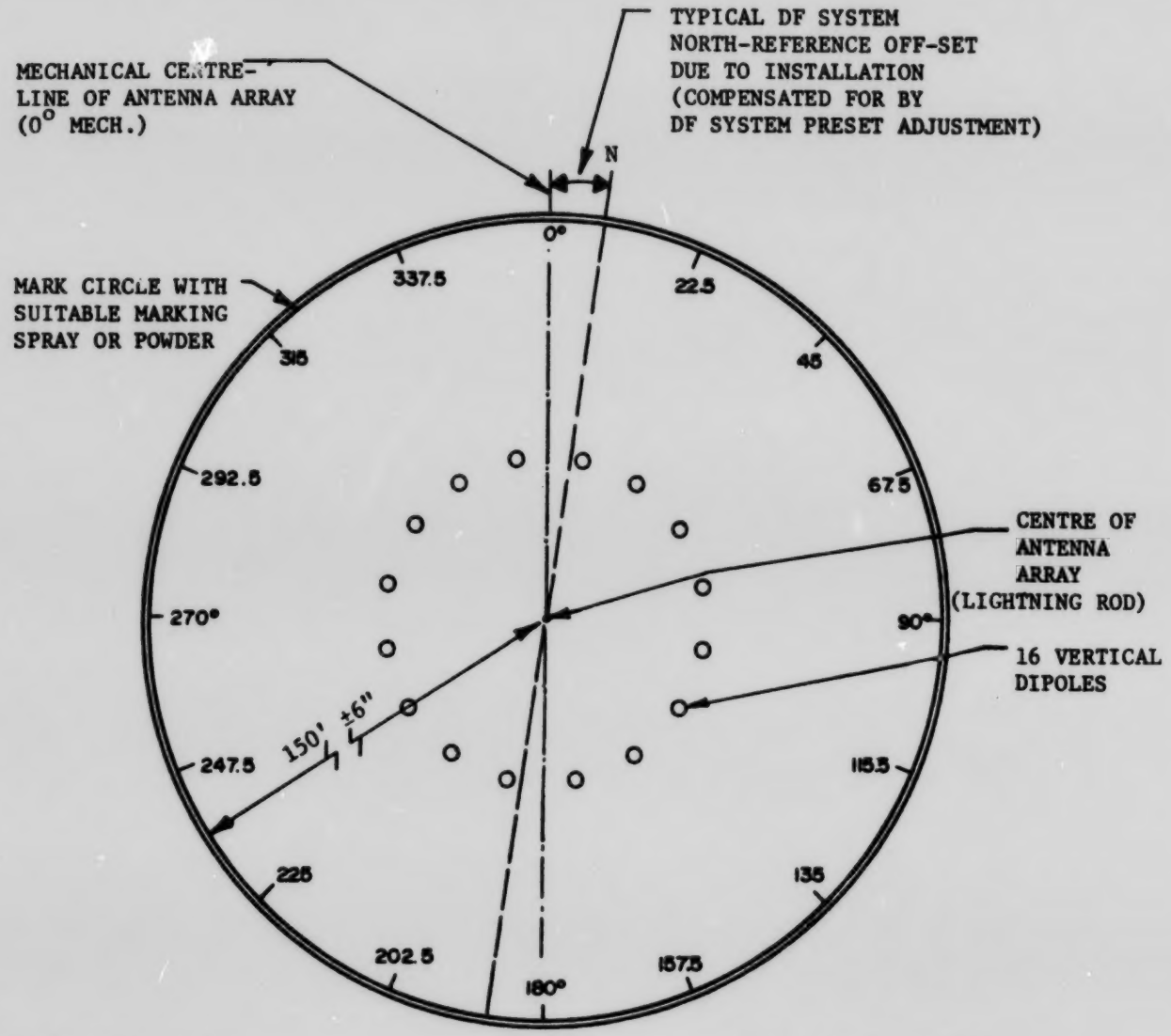
_____

Signed -

_____

Location: _____

Date: _____



N=θ° TRUE AZIMUTH SPECIFIED BY ATC REGULATIONS

NOTE: Azimuth degrees are for text reference only (do not mark).

FIGURE 6-1

CALIBRATION CIRCLE FOR ANTENNA ARRAY

(SCHEMATIC OVERHEAD VIEW)

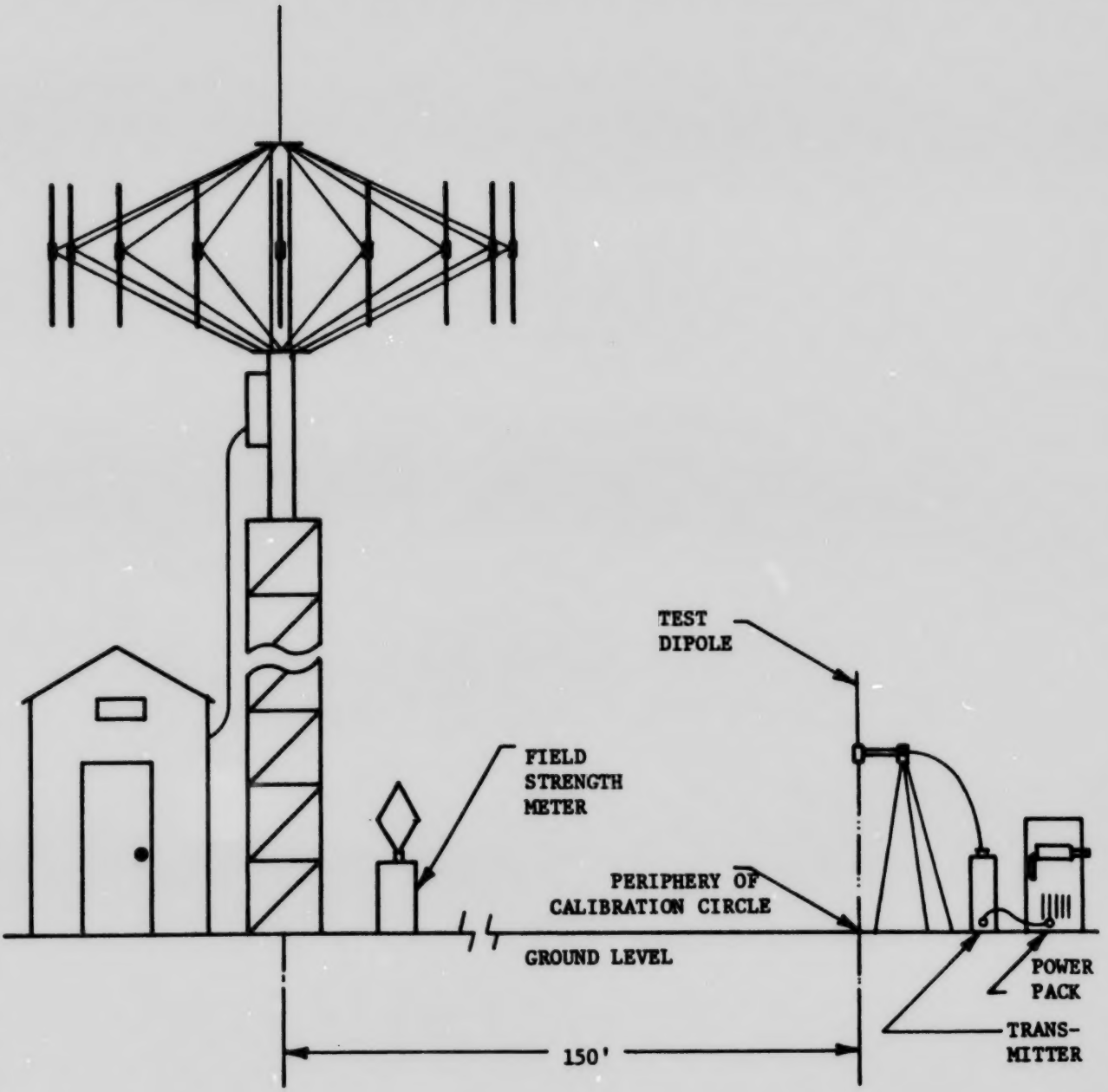


FIGURE 6-2

TEST SET-UP SCHEMATICAL VIEW

(GROUND LEVEL)

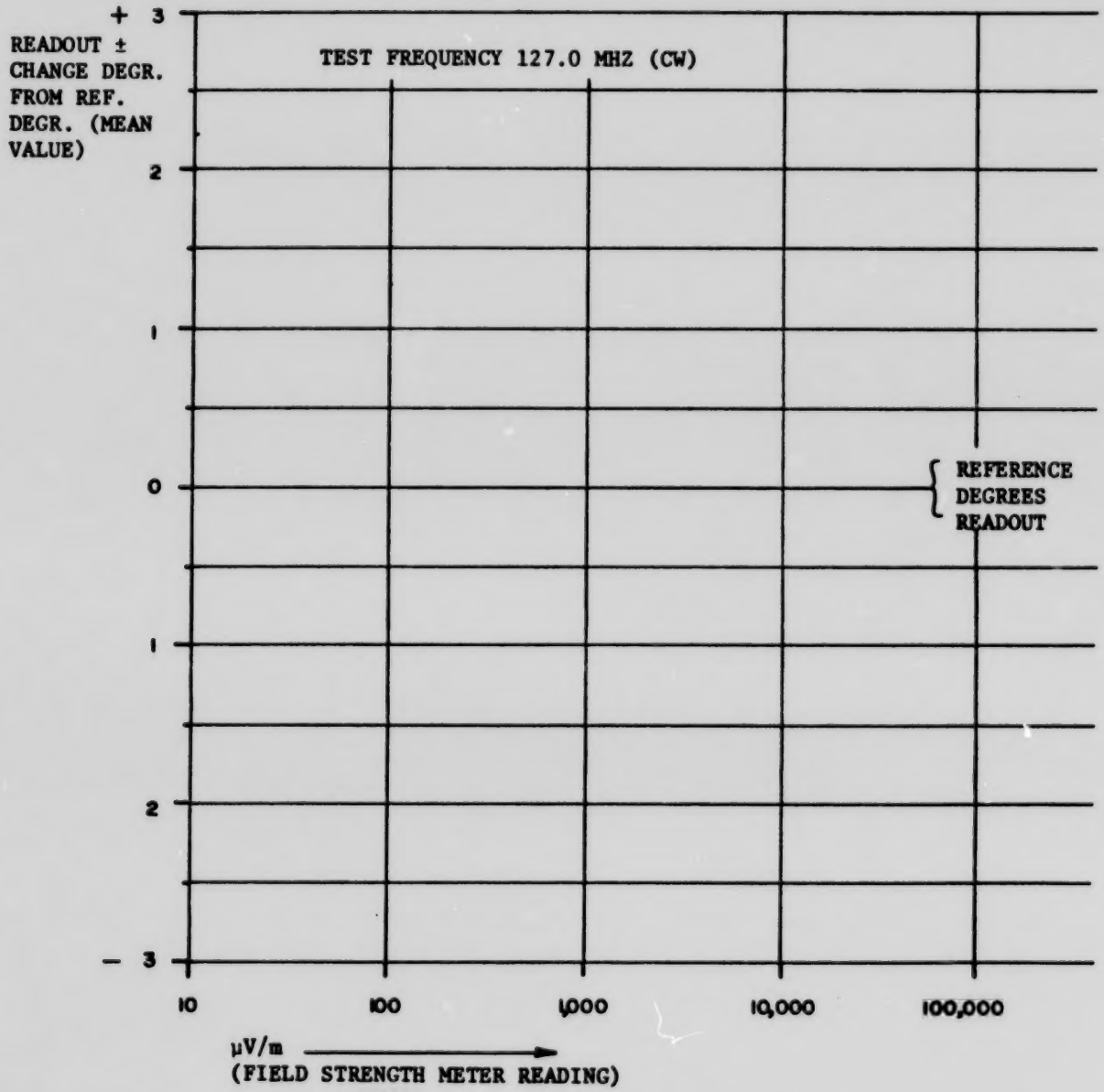
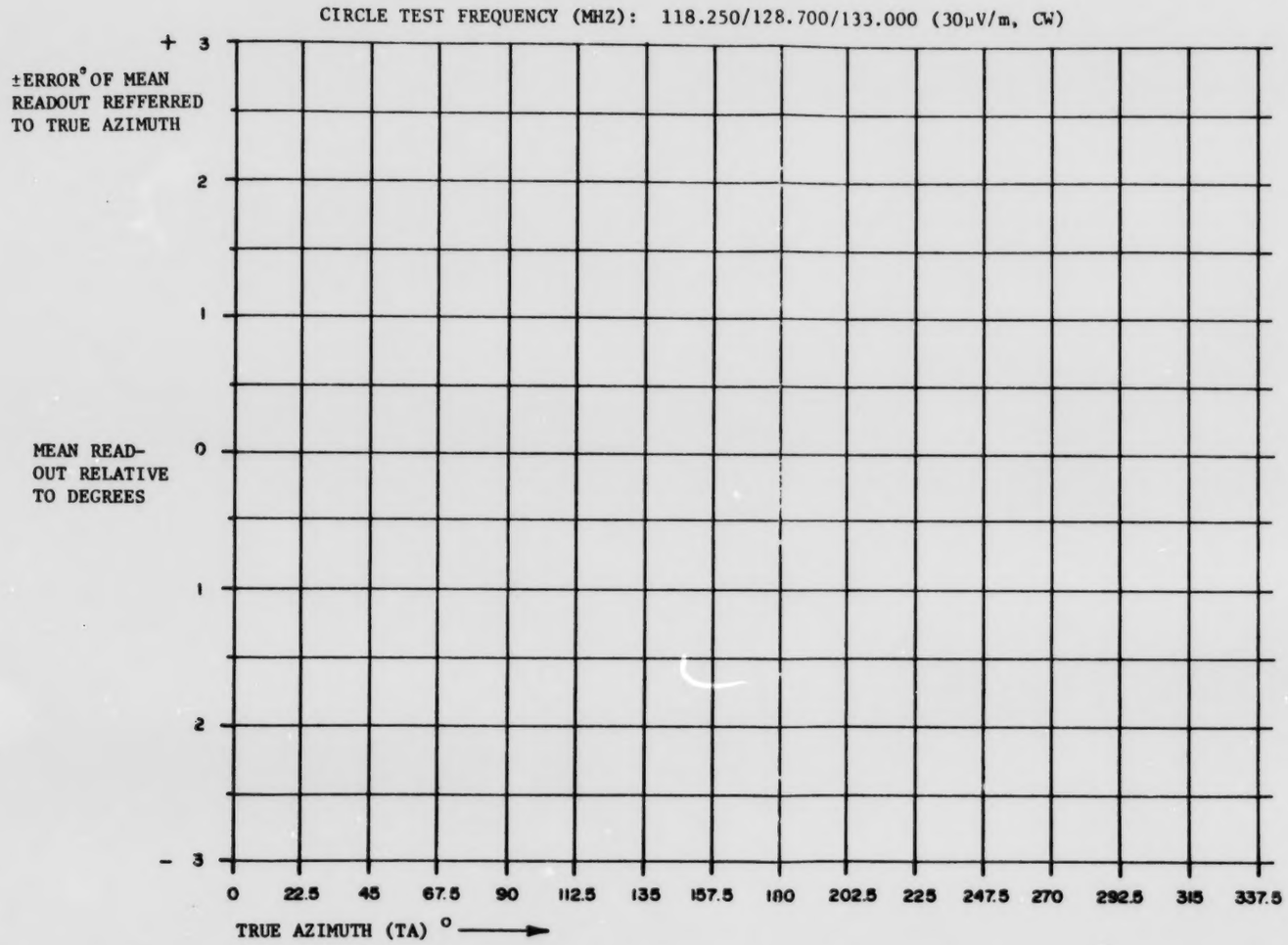


FIGURE 6-3

STRONG-SIGNAL EFFECT ON BEARING READOUT



NOTE: This graph is valid only if the df system North ref. has been correctly preset.

FIGURE 6-4

BEARING READOUT ERROR REFERRED TO TRUE AZIMUTH

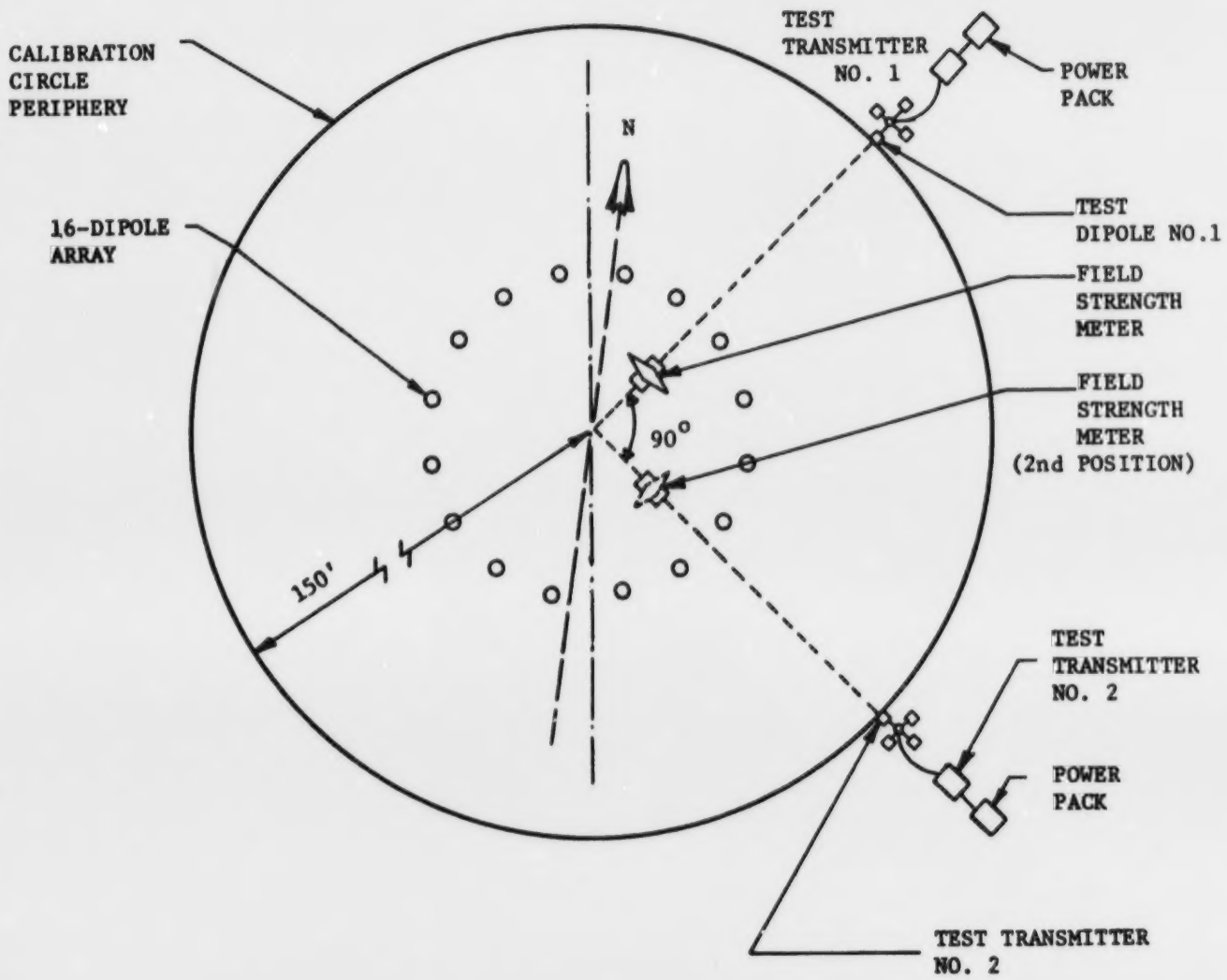


FIGURE 6-5

TEST SET-UP FOR TWO TRANSMITTERS

(OVERHEAD VIEW)

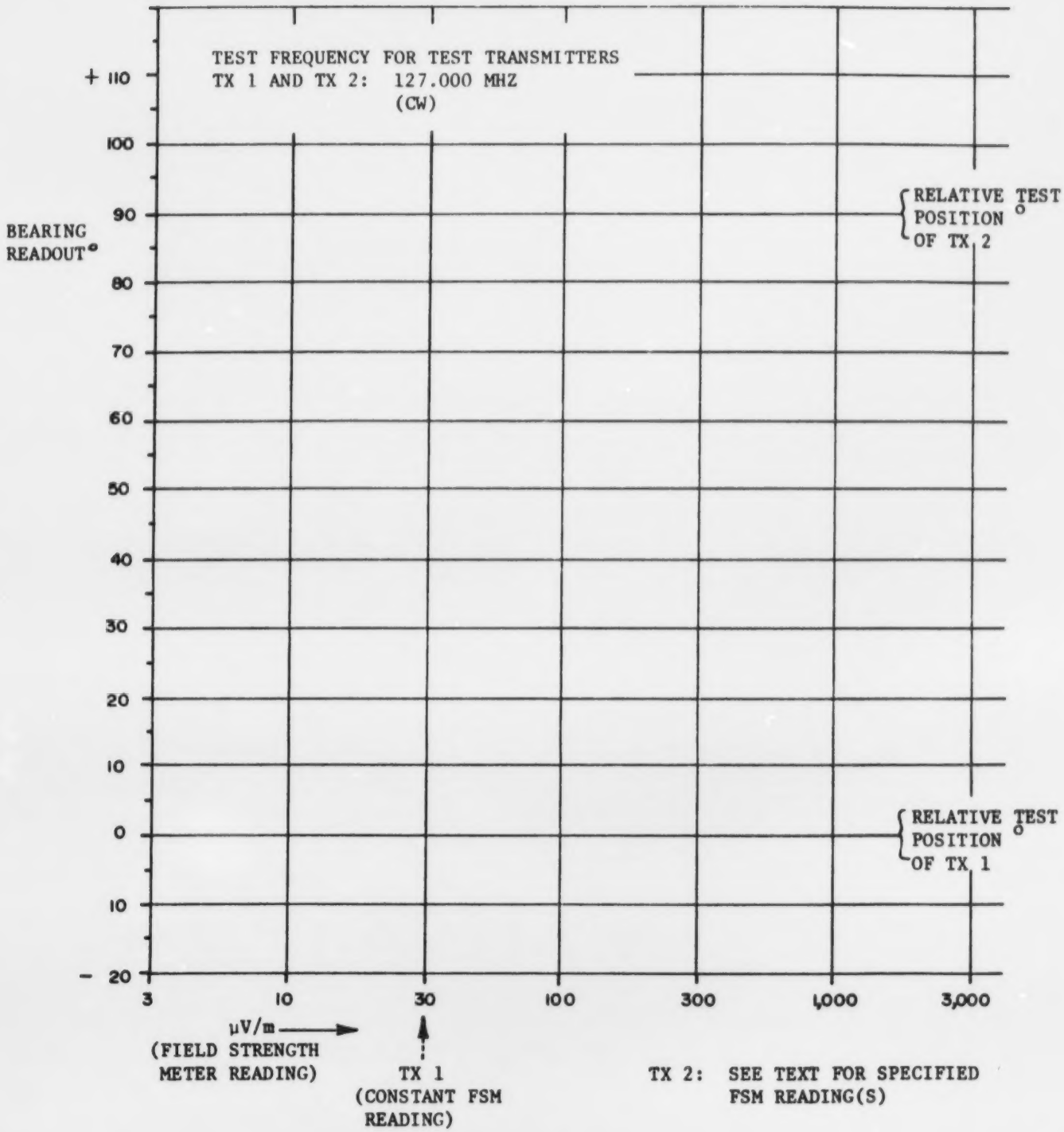


FIGURE 6-6

PLOT OF BEARING READOUT CROSSOVERS

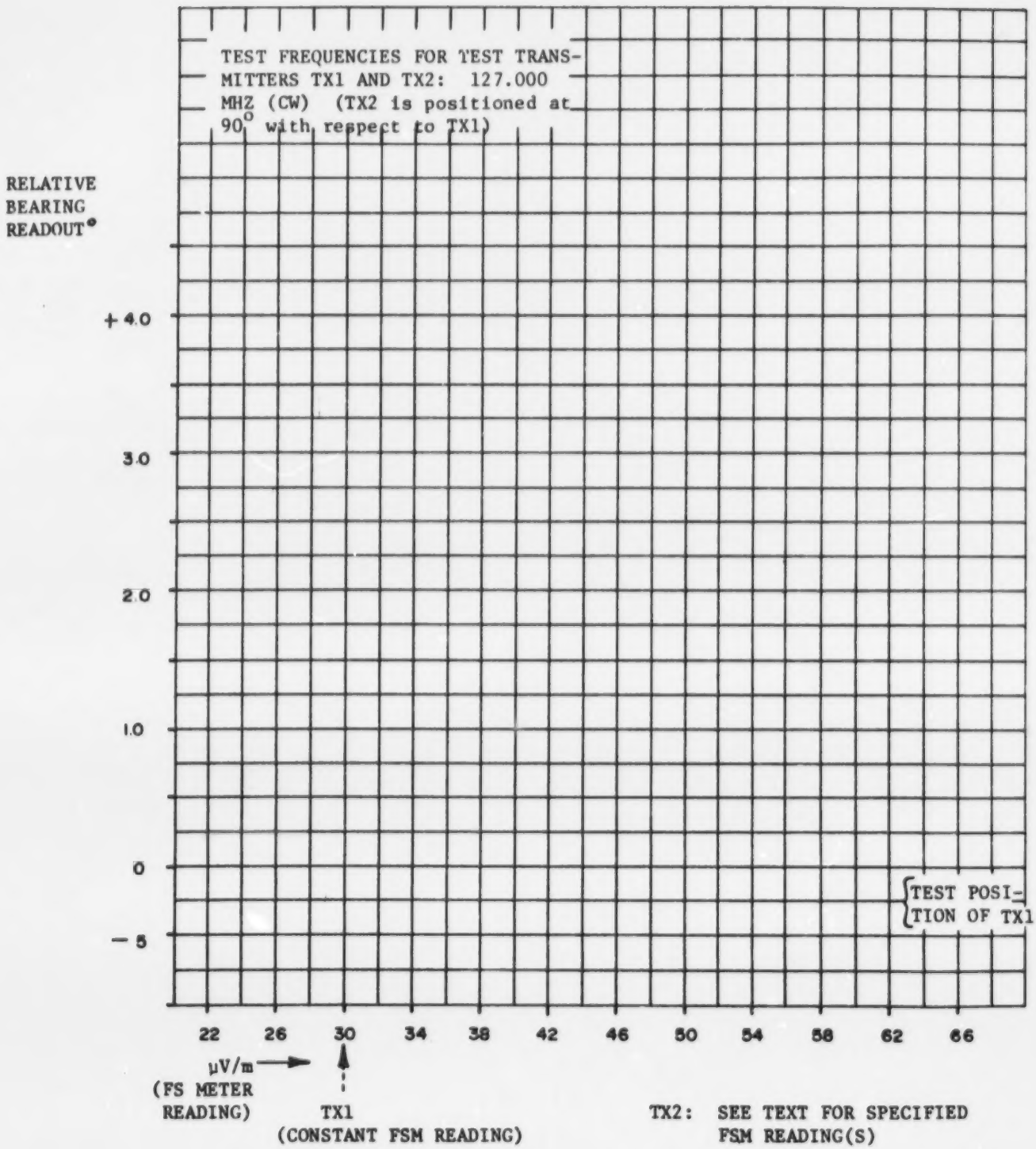


FIGURE 6-7

PLOT OF BEARING READOUT CROSSOVER SLOPE

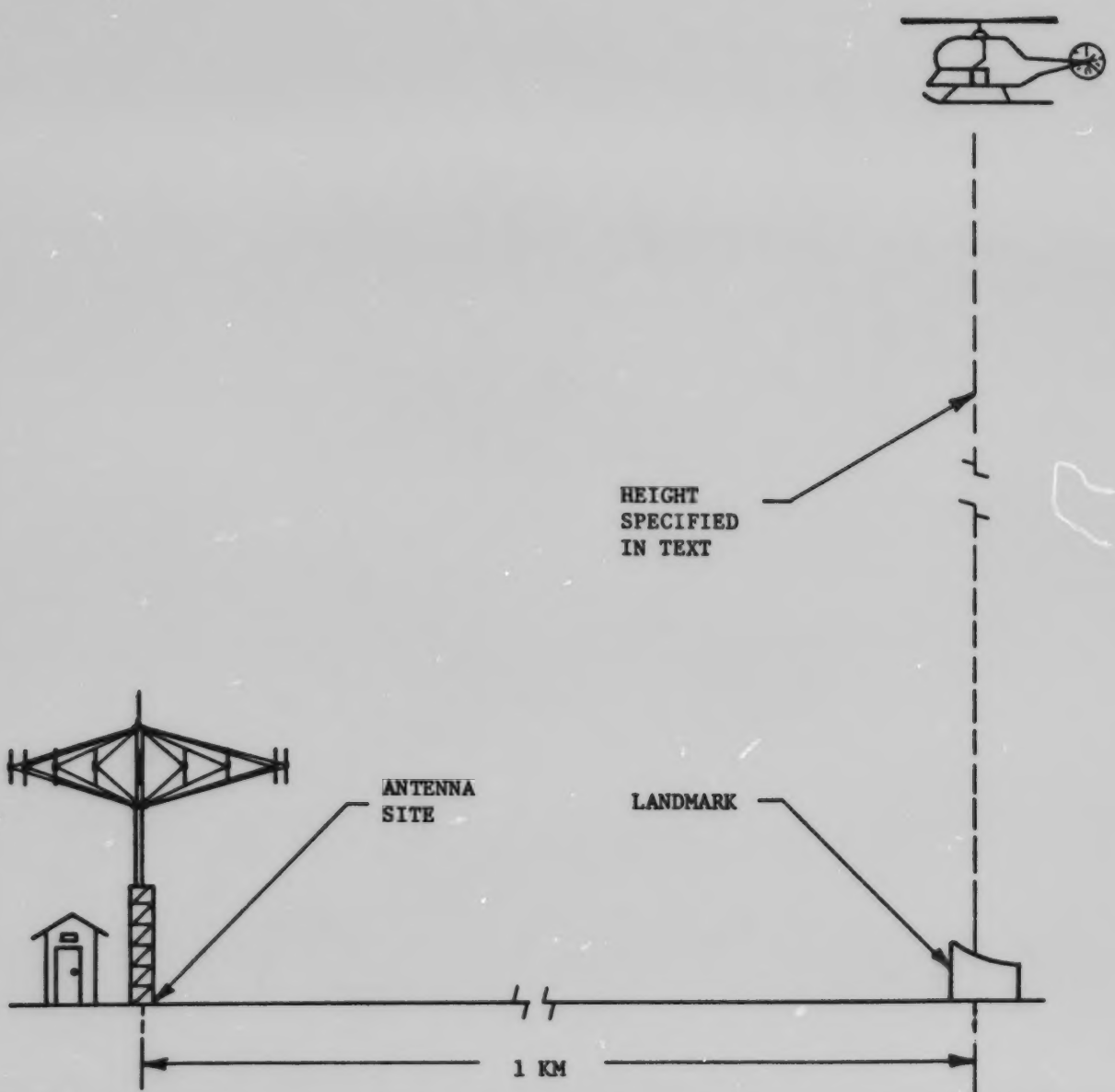


FIGURE 6-8

TEST SET-UP FOR ELEVATION TESTS

APPENDIX 4

SYSTEM FIELD PERFORMANCE TEST PROCEDURE

MARCH 1983

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1.0 PRELIMINARY REQUIREMENTS

1.1 System Installation

The system field performance test procedures are to be performed on one complete set of system equipment as installed at an operational site.

Adjustment or calibration of the equipment is not permitted during the field performance tests. If any adjustment or calibration becomes necessary, all of the field performance test procedures must be repeated.

For the purposes of the tests, a calibration (azimuth) circle (see 3.0 and Figure 6-1) must be carefully marked out on the ground. Observe that the system North (0°) reference (preset adjustment) must agree with the 0° azimuth angle marked on the calibration circle. The method of determining the 0° azimuth point is subject to air-traffic control (ATC) regulations.

1.2 System Operating Conditions

Before starting the tests, a minimum 20-minute equipment warm-up period is required.

During the tests, the system is to be operated entirely from the front control/display panel on the Receiver Unit. For this purpose, the LOCAL/REMOTE switch toggle must be set to the LOCAL position.

2.0 ARRANGEMENT OF TEST PROCEDURES

The system field performance test procedures are arranged under Section 5.0 in test number order with title. The corresponding test log sheets, also in test number order, are grouped in Section 6.0. By performing the procedures in test number sequence, the handling and operation of test equipment is to some extent simplified. However, the procedure may be performed in any order.

A space on the test log sheet(s) is intended for the signatures of two competent witnesses of the test(s).

3.0 ILLUSTRATIONS

Figures 6-1 through 6-8 provide pictorial and other information of use during the test procedures. The illustrations are inserted immediately after the test log sheets.

4.0 TEST EQUIPMENT AND OTHER ITEMS REQUIRED

The following test equipment and other items are required in order to perform the system field performance test procedures. Where applicable, equivalent test equipment and items may be used.

Item	Qty	Description/Type/Model
1	2	Test transmitter: VHF band; peak continuous r-f output power _____; modulation modes CW, AM, FM; Model _____.
2	1	R-f power amplifier: VHF band; input power _____; output power _____ max; complete with accessories for use with Item 1.
3	2	Test dipole: VHF band; with cable and accessories for use with Item 1; complete with attachments for vertical mounting on Item 4.
4	2	Tripod: height _____cm; with suitable brackets for vertical mounting in Item 3; made by _____ (Type _____).
5	2	Portable power generator pack: 120 Vac, _____ VA; for use with Item 1; _____ Model.

Item	Qty	Description/Type/Model
6	1	Field strength meter: VHF band with calibrated antenna; range of measurement to cover 1 V/m through 100mV/m (approx.); for use with Item 1.
7	1	Elevation simulator test jig.

5.0 FIELD PERFORMANCE TESTS

Ensure that the mandatory preliminary requirements of Section 1.0 are in effect at all times.

Perform the following tests in test-number order (preferably). Enter all test results in the corresponding test log sheet(s) in Section 6.0. Obtain competent-witness signatures for the test log sheet(s) as applicable.

5.1 TEST NO. 1 SYSTEM DF SENSITIVITY (CW MODE)

5.1.1 Specification Limits

System sensitivity (vertical polarization):

$\leq 3\mu V/m$ for $\leq 3^{o}$ BEARING readout spread.

5.1.2 Test Equipment (Section 4.0)

Item 1	Test Transmitter	(1)
Item 3	Test dipole	(1)
Item 4	Tripod	(1)
Item 5	Power generator pack	(1)
Item 6	Field strength meter	(1)

5.1.3 Calibration Circle

Mark out a calibration circle according to Figure 6-1.

5.1.4 Obstruction Clearance for Test

Remove small metal objects, eg, wire, cans, boxes, tools, etc, to any location not less tha 200 feet distance from the antenna tower. Remove large metal objects, eg, vehicles, frames, ladders, etc, to any location not less tha 400 feet distance from the antenna tower.

5.1.5 Test Procedure

NOTE

Figure 6-2 is a pictorial view (at ground level) of the general test set-up.

a Set up the test dipole at any selected angle on the calibration circle (Figure 6-1).

b Connect the test transmitter to the test dipole and power pack.

c Ensure that the transmitter and auxiliary equipment are positioned behind the test dipole and outmost from the calibration circle.

d Position the field strength meter under the antenna array and within the array circumference. Ensure that the meter antenna is properly aligned with the test antenna.

e Select test frequency 118.250 MHz on test transmitter and on the df system control panel.

f On the test transmitter, select modulation-mode CW.

g Set test transmitter output level to obtain 3μV/m reading on field strength meter. (NOTE: After Tx set-up, remove fsm from testing area.)

h On the df system control panel, set INTEGR SEC switch to '.8' position. Observe BEARING display readout and record the minimum reading and maximum reading obtained over at least 10 consecutive update readings. (NOTE: 'Update' means that the bearing readout changes slightly for successive bearing calculations made by the equipment.) Enter min/max readings in the appropriate spaces on TEST NO. 1 LOG sheet.

i Repeat steps e through g except set testing frequency to 128.6 MHz.

j Repeat steps e through g except set testing frequency to 133.0 MHz.

k Obtain signatures on test log sheet(s).

5.2 TEST NO. 2 EFFECT OF CONTROLLED VARIATIONS IN TEST SIGNAL OPERATING CONDITIONS

5.2.1 Purpose of Test

This test is intended to record the effect produced on the BEARING display readout due to controlled variations in the test signal operating conditions. The information obtained is to be recorded in the appropriate spaces of TEST NO. 2 LOG sheet. Observe that there are no specifications to be met. These test results are to be regarded as INFORMATION ONLY.

5.2.2 Test Equipment (Section 4.0)

Item 1	Test Transmitter	(1)
Item 2	R-f power amplifier	(1)
Item 3	Test Dipole	(1)
Item 4	Tripod	(1)
Item 5	Power generator pack	(1)
Item 6	Field strength meter	(1)

5.2.3 Calibration Circle

Mark out a calibration circle according to Figure 6-1.

5.2.4 Obstruction Clearance for Test

Remove small metal objects, eg, wire, cans, boxes, tools, etc, to any location not less than 200 distance from the antenna tower. Remove large metal objects, eg, vehicles, frames, ladders, etc, to any location not less than 400 feet distance from the antenna tower.

5.2.5 Test Procedure

NOTE

Figure 6-2 is a pictorial view (at ground level) of the general test set-up.

a Set up the test dipole on the calibration circle at any selected angle.

b Connect the test transmitter to the test dipole and the power pack.

c Ensure that the test transmitter and auxiliary equipment are positioned behind the test dipole and outermost from the calibration circle.

d Position the field strength meter under the antenna array and within the array circumference. Ensure that the meter antenna is properly aligned with the test antenna.

e On df system control panel, select frequency 127.0 MHz.

f On test transmitter, select frequency 127.0 MHz and modulation mode CW.

g Set test transmitter output level to obtain 10μV/m reading on field strength meter. (After use, remove the fsm from the testing area.)

h On the df system control panel, set INTEGR SEC switch to '.8' position. Observe BEARING display readout and record the minimum and maximum readings obtained over at least 10 consecutive update readings. (NOTE: 'Update' means that the bearing readout changes slightly for successive bearing calculations made by the equipment.) Enter the min/max readings in the appropriate spaces of TEST NO. 2 LOG sheet.

i Use the min/max readings recorded in step h above to calculate the average (arithmetic mean) value of each BEARING readout. Enter this value in the appropriate spaces on TEST NO. 2 LOG sheet.

j Repeat steps f through i above except set test transmitter frequency to 127.003 MHz (approx. +25ppm detune from channel centre frequency). DO NOT change the df system channel frequency of 127.0 MHz.

k Repeat steps f through i except set test transmitter frequency to 127.006 MHz (approx. +50ppm detune from channel centre frequency).

l Repeat steps f through i except set test transmitter frequency to 126.997 MHz (approx. -25ppm detune from channel centre frequency).

m Repeat steps f through i except set test transmitter frequency to 126.994 MHz (approx. -50ppm detune from channel centre frequency).

n Repeat steps f through i above except, on test transmitter, set modulation mode to AM, 1000 Hz tone modulation depth 30%.

o Repeat steps f through i except, on test transmitter, set modulation mode to FM, 1000 Hz tone, modulation deviation 3kHz.

p Check that the test transmitter is set to 127.0 MHz, CW mode, and 10 V/m on field strength meter. (After Tx set up, remove fsm from testing area.) The df system must remain on channel frequency 127.0 MHz.

q Repeat steps h and i.

NOTE

In step r following, the larger field strength requirements will necessitate the connection of test equipment Item 2 (r-f power amplifier) to Item 1 (test transmitter).

r Repeat step p (with h and i) seven times, except each time increment the test tramsmitter output by a nominal 10 dB step (ie, for each step in order, obtain an fsm reading of 3, 10, 100, 300, 1,000 or 3,000 micro-volts per meter).

s Obtain signatures on test log sheet.

5.3 TEST NO. 3 DF SYSTEM INSTALLATION ACCURACY (CW MODE)

NOTE

Test No. 3 begins with an initial check of the df system NORTH REFERENCE offset with the antenna mounted on the turntable and locked in the reference position. Subsequently, the antenna is rotated in calibrated steps and bearings are obtained for each antenna position.

5.3.1 Specification Limits

Df accuracy: 1.5° BEARING readout error with respect to relative azimuth angle for specified test frequencies. Three frequencies are used: 118.25 MHz, 128.6 MHz and 133.0 MHz.

5.3.2 Test Equipment (Section 4.0)

Item 1	Test transmitter	(1)
Item 3	Test dipole	(1)
Item 4	Tripod	(1)
Item 5	Power generator pack	(1)
Item 6	Field strength meter	(1)

5.3.3 Calibration Circle

Mark out a calibration circle according to Figure 6-1.

Mark position for test transmitter at a radius of 180 feet, starting with the North Reference (0°) and spaced around at 22.5° intervals.

5.3.4 Obstruction Clearance for Test

Remove small metal objects, eg, wire, cans, boxes, tools, etc, to any location not less than 200 feet distance from the antenna tower. Remove large metal objects, eg, vehicles, frames, ladders, etc, to any location not less than 400 feet distance from the antenna tower. Additionally, for the test procedure (5.3.5), all cleared obstructions must be placed approximately 180° opposite the test dipole (ie, on the other side of the antenna array).

5.3.5 Test Procedure

NOTE

Figure 6-1 shows a typical df system installation offset of the antenna array centreline (0° mechanical) with respect to true azimuth (Ta)°. This offset will be electronically pressed during instalation.

a Refer to Figure 6-1. Locate the 0° true azimuth line (marked 'N') according to Air Traffic Control (ATC) regulations. This 0° line is marked at a distance of 180 feet in the 'N' direction with an angular accuracy of 0.1°. The purpose of this line is to place the test dipole (with transmitter) on the line and as far distant from the antenna array as may be practicable.

b Set up the test dipole on the 'N' line marker.

c Connect the test transmitter to the test dipole and power pack.

d Ensure that the test transmitter and power pack are positioned behind the test dipole (with respect to testing direction).

f Select test frequency 118.25 MHz on the test transmitter and on the df system control panel.

f On the test transmitter, select modulation-mode CW.

g Set the antenna turntable to zero position.

h Set test transmitter output level to obtain 30μV/m on the field strength meter. (NOTE: As reference, use the output level obtained under 5.1.5 g and add 20 dB.)

i On the df system control panel, set INTEGR SEC switch to '.8' position.

j Observe the BEARING display readout noting the minimum and maximum indications over approx. 10 seconds.

k 1 Repeat bearing readouts with the test transmitter level set at 3 V/m and 1mV/m.

2 On TEST NO. 3 LOG sheet, make an entry (in the appropriate space) to record the df system NORTH REFERENCE.

3 Move the antenna turntable to the next position, etc. and repeat j-k making note of the new bearing readings

NOTE

The test dipole set-up angles specified hereunder for the calibration circle are antenna array mechanical angles starting with 0° and proceeding through 11.25° intervals to cover 360°. These angles are accurate to ±0.1°, by virtue of mechanical precision of the turntable.

CAUTION

The test dipole position on the calibration circle is required to have an accuracy of $\pm 0.1^{o}$ (corresponding to ± 3 inches along the arc of the circle). The test dipole must not be moved for the duration of this test.

l Select test frequency 128.6 MHz on test transmitter and on the df system control panel.

m On the test transmitter, select modulation-mode CW.

n Set test transmitter output level to obtain 30μV/m reading on the field strength meter.

o On the df system control panel, set INTEGR SEC switch to '.8' position. Repeat the antenna rotation procedure and observe BEARING display readout and record the minimum reading and maximum reading obtained, approximately 10 seconds. Enter min/max readings in the appropriate spaces on TEST NO. 3 LOG sheet.

p On TEST NO. 3 LOG sheet, enter the bearing error into the appropriate spaces. Observe the maximun and minimum errors for each frequency over the full circle of rotation.

NOTE

The specified maximum bearing error is the sum of the system installation errors. It should not include a North reference error, which may be due to local re-radiation at the transmitter site.

q Repeat steps 1 through p, except set testing frequency to 128.7 MHz.

r Repeat steps 1 through p, except set testing frequency to 133.0 MHz.

s Repeat steps e through r except, for positioning the test transmitter at the 270° marker.

t Obtain signatures on test log sheet.

u Return transmitter and test dipole to the zero reference marker.

5.4 TEST NO. 4 BEARING READOUT CHANGE WITH RESPECT TO POLARIZATION ANGLE (CW MODE)

5.4.1 Specification Limits

Bearing readout error for a test dipole angle of 45° from the vertical in a plane tangential to the calibration circle (see 5.4.3).

1° change from bearing readout made with the test antenna in the normal vertical position.

5.4.2 Test Equipment (Section 4.0)

Item 1	Test transmitter	(1)
Item 3	Test dipole	(1)
Item 4	Tripod	(1)
Item 5	Power generator pack	(1)
Item 6	Field strength meter	(1)

5.4.3 Calibration Circle

Use the a calibration circle as marked for 5.1 and 5.2

5.4.4 Obstruction Clearance for Test

Remove small metal objects, eg, wire, cans, boxes, tools, etc, to any location not less than 200 feet distance from the antenna tower. Remove large metal objects, eg, vehicles, frames, ladders, etc, to any location not less than 400 feet distance from the antennna tower.

5.4.5 Test Procedure

NOTE

Figure 6-2 is a pictorial view (at ground level) of the general test set-up.

a Set up the test dipole on the calibration circle at 0° reference. The test dipole must be vertical.

b Connect the test transmitter to the test dipole and power pack.

c Ensure that the test transmitter and auxilary equipment are positioned behind the test dipole and outermost from the calibration circle.

d Set the antenna turntable to zero reference.

e Select test frequency 118.250 MHz on the test transmitter and on the df system.

f ON the test transmitter, select modulation-mode CW.

g Set test transmitter output level to obtain 30 V/m reading on the field strength.

h On the df system control panel, set INTEGR SEC switch to '.8' position.

i Observe the test readout appearing on system control panel BEARING display and record this TEST NO. 4 LOG sheet (in the appropriate space).

j At the test dipole, mentally construct the vertical plane tangential to the calibration circle. Rotate the test dipole, clockwise, in this plane until it is at an angle 45° to the vertical. Maintain this test dipole angle.

k Repeat step i.

l Rotate the test dipole anticlockwise by 45° and repeat step i

m Reset the test dipole to its normal vertical angle.

n Repeat steps e through l except set testing frequency to 128.6 MHz.

o Repeat steps e through l except set testing frequency to 133.0 MHz.

p Repeat steps a through o except, for each repeat procedure, increment the antenna turntable position angle by 90°.

q Obtain signatures on test log sheet.

5.5 TEST NO. 5 ADJACENT CHANNEL BREAKTHROUGH EFFECT ON BEARING READOUT (CW MODE)

5.5.1 Specification Limits

Breakthrough effect due to a properly-centered 'unwanted' adjacent channel test signal displaced 90° from a 'wanted' test signal and within the following field strength constraints: unwanted signal 1mV/m and 30 dB above the level of the wanted signal.

The bearing readout change due to the above unwanted signal shall be limited as follows: $\pm 1^{\circ}$ with respect to the BEARING readout (reference) for the wanted signal when the unwanted signal is not present.

5.5.2 Test Equipment (Section 4.0)

Item 1	Test Transmitter	(2)
Item 2	R-f power amplifier	(1)
Item 3	Test dipole	(2)
Item 4	Tripod	(2)
Item 5	Power generator pack	(2)
Item 6	Field strength meter	(1)

5.5.3 Calibration Circle

Use the calibration circle according to Figure 6-1.

5.5.4 Obstruction Clearance for Test

Remove small metal objects, eg, wire, cans, boxes, tools, etc, to any location not less than 200 feet distance from the antenna tower. Remove large metal objects, eg, vehicles, frames, ladders, etc, to any location not less than 400 feet distance from the antenna tower.

5.5.5 Test Procedure

NOTE

Figure 6-5 is a pictorial view (overhead) of the general test set-up.

a Set up one test dipole (No. 1) on the calibration circle at any selected azimuth angle. (e.g. zero ref. position)

b Set up the other test dipole (No.2) on the circle at a position angularly displaced from dipole No. 1 by 270° in a clockwise direction (overhead view).

c Connect test transmitter No. 1 (without r-f power amplifier) to test dipole No. 1 and to its power pack.

d Connect test transmitter No. 2 (with r-f power amplifier to test dipole No. 2 and to its power pack. DO NOT switch-on this transmitter until it is required.

e Ensure that the test transmitters and auxiliary equipment are positioned behind the test dipoles and outermost from the calibration circle.

f Set the antenna turntable position to zero reference.

g On test transmitter No. 1, select test frequency 118.25 MHz and modulation-mode CW. Select df system frequency 118.25 MHz.

h Set test transmitter No. 1 output level to obtain 30 μV/m.

i On the df system control panel, set INTEGR SEC switch to '.8' position. Record the BEARING display readout on TEST NO. 5 LOG sheet.

j On test transmitter No. 2, select test frequency 118.275 MHz (adjacent channel) and modulation mode CW.

k Set test transmitter No. 2 (with r-f power amplifier) output level to obtain 1mV/m (30 dB above test transmitter No. 1 level).

l Record the BEARING display readout on TEST NO. 5 LOG sheet.

NOTE

Steps m and n following are not tests. They are intended only for observation of the system behaviour under adverse conditions.

m Repeat steps j through l except set test transmitter No. 2 (only) test frequency to 118.300 MHz.

n Repeat steps j through l except set test transmitter No. 2 (only) test frequency to 118.325 MHz.

o Obtain signatures on test log sheet.

5.6 TEST NO. 6 EFFECT OF TWO TEST SIGNALS RECEIVED IN THE SAME CHANNEL AND ANGULARLY DISPLACED BY 90° (CW MODE)

5.6.1 Purpose of Test

This test is intended to record the effect produced on the BEARING display readout when two test signals of identical frequency and variable field strengths are received in one selected channel. The information obtained is to be recorded in the appropriate spaces of TEST NO. 6 LOG sheet. Observe that there are no specifications to be met. These test results are to be regarded as INFORMATION ONLY.

5.6.2 Test Equipment (Section 4.0)

Item 1	Test transmitter	(2)
Item 2	R-f power amplifier	(1)
Item 3	Test dipole	(2)
Item 4	Tripod	(2)
Item 5	Power generator pack	(2)
Item 6	Field strength meter	(1)

5.6.3 Calibration Circle

Mark out a calibration circle according to Figure 6-1.

5.6.4 Obstruction Clearance for Test

Remove small metal objects, eg, wire, cans, boxes, tools, etc, to any location not less than 200 feet disatance from the antenna tower. Remove large metal objects, eg, vehicles, frames, ladders, etc, to any location not less than 400 feet distance from the antenna tower.

5.6.5 Test Procedure

NOTE

Figure 6-5 is a pictorial view (overhead) of the general test set-up.

a Set up one test dipole (No. 1) on the calibration circle at any selected array angle. (e.g. at 0° reff. point)

b Set up the other test dipole (No. 2) on the circle at a position angularly displaced from dipole No. 1 by 270° in a clockwise direction (overhead view).

c Connect test transmitter No. 1 (without r-f power amplifier) to test dipole No. 1 and to its power pack.

d Connect test transmitter No. 2 (with r-f power amplifier) to test dipole No. 2 and to its power pack. DO NOT switch-on this transmitter until it is required.

e Ensure that the test transmitter and auxiliary equipment are positioned behind the test dipoles and outermost from the calibration circle.

f Set the antenna turntable to position zero reference.

g On test transmitter No. 1, select test frequency 127.0 MHz and modulation mode CW. Select df system frequency 127.0 MHz.

h Set test transmitter No. 1 output level to obtain 30 V/m field strength. This output is to remain constant throughout the test.

i On the df system control panel, set INTEGR SEC switch to '.8' position. Record the BEARING display readout on TEST NO. 6 LOG sheet.

j On test transmitter No. 2, select test frequency 127.0 MHz and modulation mode CW.

k Set test transmitter No. 2 output level to obtain 3 V/m reading on the field strength meter. (NOTE: After Tx set-up, remove fsm from testing area.)

l Repeat step i above.

NOTE

In step m following, the larger field strength requirements may necessitate the connection of test equipment Item 2 (r-f amplifier) to Item 1 (test transmitter).

m Repeat steps k and i (in that order) six times, except each time increment the test transmitter No. 2 output by a nominal 10 dB step (ie, for each step in order, obtain field strength of 10, 30, 100, 300 or 1000 micro-volts per meter).

NOTE

Step m above should show (on Figure 6-6) a 'takeover' of the absolute BEARING readout from the Tx1 bearing to the Tx2 bearing. When the signal strengths of Tx1 are similar, the bearing will be blanked out. More accurate figures of the takeover may be obtained as follows:

n Switch-off test transmitter No. 2. (This will allow the df system to 're-capture' the test transmitter No. 1 bearing.)

o Set test transmitter No. 2 output level to obtain 5μV/m field strength.

p Repeat step i above.

q Repeat steps o and i above (in that order), each time incrementing the test transmitter No. 2 output by a nominal three dB step (ie, for each step in order, set the field strength to 17, 50, 170 and 500 V/m.)

r Obtain signatures on test log sheet.

5.7 TEST NO. 7 BEARING READOUT CHANGE FOR HIGH-ANGLE ELEVATION WITH OVERHEAD-PASS INDICATION

5.7.1 Specification Limits

Referred to a df system BEARING display readout obtained for a minimum elevation angle (effectively 0°), any change in the BEARING readout for an elevation angle of 45° (approx.) shall not exceed ±1°.

The df system OVERHEAD PASS light (blue) should start flashing with the elevation-angle limits of 60 ±5°. Owing to difficulties of making measurements on a moving plane, this performance will be simulated by electronic means.

5.7.2 Test Equipment (Section 4.0)

Item 1	Test transmitter	(1)
Item 3	Test dipole	
Item 4	Tripod	(1)
Item 5	Power generator pack	(1)
Item 7	Elevation simulator test jig	(1)
Item 8	Oscilloscope	(1)

5.7.3 Calibration Circle

A calibration circle is required as per fig. 6-1.

5.7.4 Obstruction Clearance for Test

Remove small metal objects, eg, wire, cans, boxes, tools, etc, to any location not less than 200 feet distance from the antenna tower. Remove large metal objects, eg, vehicles, frames, ladders, etc, to any location not less than 400 feet distance from the antenna tower.

5.7.5 Test Procedure

a Set test dipole and transmitter at position zero reference on the calibration circle.

b Set test frequency to 118.25 MHz and signal level to 30 V/m field strength.

c Set antenna turntable to zero position.

d Obtain bearing readout.

e Insert the elevation test jig into the DF receiver output lines (in frontof the phase detector).

f Connect oscilloscope to output of phase detector and trigger from North Reference test point. Observe the phase detector waveform and the peak-to-peak amplitude.

g Insert a variable resistance into the test jig and reduce its value until the bearing readout disappears and the OVERHEAD light starts flashing.

h Observe the amplitude of the phase detector waveform and calculate its % reduction with respect to f.

NOTE

50% reduction corresponds to an elevation of 60°.

i Increase resistance to restore the bearing readout until the amplitude reduction is 71.5%.

j Observe the bearing readout and compare with d.

NOTE

The difference between readouts of d and j corresponds to an error at an elevation of 45°.

6.0 TEST LOG SHEETS FOR QUASI-DOPPLER DF SYSTEM XXXX FIELD PERFORMANCE TESTS

This section contains the test log sheets for the field performance test procedures described in Sections 1.0 through 4.0 and detailed in Section 5.0.

In Section 5.0, each test procedure was given a test number (eg, Test No. 1). Likewise, the associated test log sheets herewith are each identified by a corresponding test log numbers (eg, Test No. 1 Log).

Each completed test log must be certified by the signatures of two competent witnesses together with the location and date of the test. When all the test logs have been certified, they provide a collective acceptance of the df system field performance test results.

6.1 TEST NO. 1 LOG SYSTEM DF SENSITIVITY (CW MODE)

a References

Section 1.0 through 4.0 (general)
Section 5.0 (field performance tests)
Sub-section 5.1 (Test No. 1, requirements and procedure)

b Test Results (field strength 3μV/m)

Test Freq. (MHz)	Bearing Readout ° Min	Max	Bearing Spread ° >3	<3
118.250	---	---	---	---
128.600	---	---	---	---
133.000	---	---	---	---

c Certification

The above test results (b) are within the specified limits: ≤3μV/m for ≤3° BEARING readout spread.

Signed - Signed -

_____ _____

Location: _____ Date: _____

6.2 TEST NO. 2 LOG EFFECT OF CONTROLLED VARIATIONS IN TEST SIGNAL OPERATING CONDITIONS

a References

Section 1.0 through 4.0 (general)
Section 5.0 (field performance tests)
Sub-section 5.2 (Test No. 2, requirements and procedure)

b Test Results

1. CW Mode Data (field strength 10μV/m)

Test Freq. (MHz)	Bear. Read.° Min.	Max.	Read. Mean°	±Change° (from Ref.)
127.000	---	---	---(Ref)	XXXX
127.603	---	---	---	----
127.606	---	---	---	----
126.597	---	---	---	----
126.594	---	---	---	----

2. AM* Mode Data (field strength 10μV/m)

Test Freq. (MHz)	Bear. Read.° Min.	Max.	Read. Mean°	±Change° (from Ref.)
127.000	---	---	---	----
	---	---	---	----
	For reference, use results of CW mode at 127.000 MHz			
	---	---	---	----
	---	---	---	----
	---	---	---	----

* 1000Hz tone, depth 30%.

3. FM* Mode Data (field strength 10 V/m)

Test Freq. (MHz)	Bear. Read.° Min.	Max.	Read. Mean°	±Change° (from Ref.)
127.000	---	---	___(Ref)	----
	---	---	---	----
	For reference, use results of CW mode at 127.000 MHz			
	---	---	---	----
	---	---	---	----
	---	---	---	----

* 1000Hz tone, deviation ±3 kHz.

4. Strong Signal Data (127.000 MHz CW mode)

Test Sig. Strength	Bear. Read.° Min.	Max.	Read. Mean°	±Change° (from Ref.)
3μV/M	---	---	---	----
10μV/m	---	---	___(Ref)	XXXX
30μV/m	---	---	---	----
100μV/m	---	---	---	----
300μV/m	---	---	---	----
1mV/m	---	---	---	----
3mV/m	---	---	---	----
100mV/m	---	---	---	----

c Certification

The above test results b are recorded for information only.

Signed -

_____

Signed -

_____

Location: _____

Date: _____

6.3 TEST NO. 3. DF SYSTEM ACCURACY

Attach tables of readings as required.

Certification

Taking the difference of the max. and min. errors, the above test results (b, 2) are within the specified limits: $\leq$ 1.5 degrees BEARING readout error, for each given test frequency.

Signed - Signed -

_____ _____

Location: _____ Date: _____

6.4 TEST NO.4 BEARING READOUT CHANGE WITH RESPECT TO POLARIZATION ANGLE (CW MODE)

a References

Section 1.0 through 4.0 (general)
Section 5.0 (field performance tests)
Sub-section 5.4 (Test No. 4, requirements and procedures)

b Test Results (field strength 30μV/m)

Test Freq. (MHz)	Antenna Position °	Bearing Vert. Polar.	Readout ° +45° Polar.	Readout ° -45° Polar	±Change ° from Vert. Read.
118.250	0.0	----------	----------	----------	----------
128.700	0.0	----------	----------	----------	----------
133.000	0.0	----------	----------	----------	----------
118.250	90.0	----------	----------	----------	----------
128.700	90.0	----------	----------	----------	----------
133.000	90.0	----------	----------	----------	----------
118.250	180.0	----------	----------	----------	----------
128.700	180.0	----------	----------	----------	----------
133.000	180.0	----------	----------	----------	----------
118.250	270.0	----------	----------	----------	----------
128.700	270.0	----------	----------	----------	----------
133.000	270.0	----------	----------	----------	----------

c Certification

The above test results (b) are within the specified limits: $\leq 1^{\circ}$ change in bearing readout for 45° polarized test dipole referred to bearing readout for vertical polarized test dipole.

Signed -

_____

Signed -

_____

Location: _____

Date: _____

6.5 TEST NO. 5 LOG ADJACENT CHANNEL BREAK-THROUGH EFFECT ON BEARING READOUT (CW MODE)

a References

Section 1.0 through 4.0 (general)
Section 5.0 (field performance tests)
Sub-section 5.5 (Test No. 5, requirements and procedures)

b Test Results (field strength: Tx No.1, 30μV/m; Tx No. 2, 1mV/m)

Test Freq. (MHz) (Tx No. 1) *	Test Freq. (MHz) (Tx No. 2) **	Bearing Readout °	Change ° from Ref
128.700	OFF	---------	XXXX
128.700	128.725	---------	----
128.700	128.720	---------	---- ***
128.700	128.715	---------	---- ***

* Wanted test signal.
** Unwanted adjacent channel test signal 90° displaced from wanted signal.
*** Not a test result. INFORMATION ONLY.

c Certification

Refer to b above. With repect to a clear 'wanted' test signal bearing readout (reference), any readout change does not exceed 1^{o} when due to the presence of a properly-centered adjacent channel 'unwanted' test signal (*** entries excepted) under the specified test signal conditions.

Signed - Signed -

_____ _____

Location: _____ Date: _____

6.6 TEST NO. 6 LOG EFFECT OF TWO TEST SIGNALS RECEIVED IN THE SAME CHANNEL AND ANGULARLY DISPLACED BY 90° (CW MODE)

a References

Section 1.0 through 4.0 (general)
Section 5.0 (field performance tests)
Sub-section 5.5 (Test No. 5, requirements and procedures)

b Test Results

1. Bearing Readout Takeover Data

Tx No. 1 V/m	Tx No. 2 V/m	Bearing Readout °	± Change ° from Ref.
30	OFF	____(Ref.)	XXXX
30	3	----	----
30	10	----	----
30	30	----	----
30	100	----	----
30	300	----	----
30	1000	----	----
		----	----

(Mark "blank" where no readout is shown)

c Certification

The above test results (b) are recorded for information only.

Signed -

_____

Signed -

_____

Location: _____

Date: _____

6.7 TEST NO. 7 LOG BEARING READ CHANGE FOR HIGH-ANGLE ELEVATION WITH OVERHEAD-PASS INDICATION

a References

Section 1.0 through 4.0 (general)
Section 5.0 (field performance tests)
Sub-section 5.5 (Test No. 5, requirements and procedures)

b Test Results

Reference	Phase Det. p-p Ampli.	Ampl. Reduction	Elevation	Bearing
No damping Resistor	--------	--------	0°	------
Overhead Start	--------	--------	---------	BLANK
Simulalted 45° elev.	--------	--------	45°	------
Bearing Error for 45°	--------	--------	---------	------

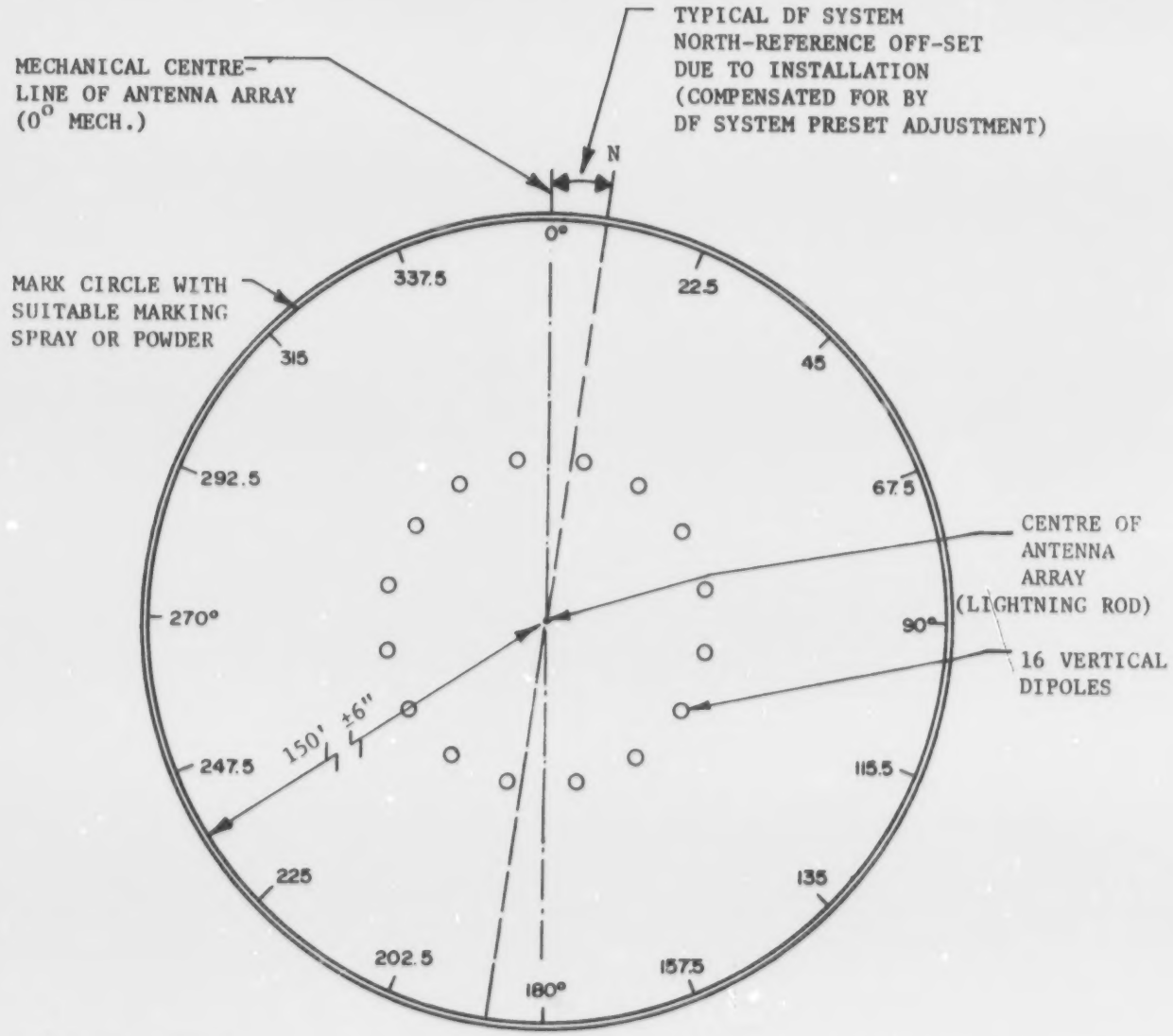
c Certification

For 45° elevation only, the bearing readout change referred to the reference readout does not exceed 1°. The OVERHEAD PASS light starts flashing within elevation angle limits 60 5°.

Signed - Signed -

_____ _____

Location: _____ Date: _____



N=0° TRUE AZIMUTH SPECIFIED BY ATC REGULATIONS

NOTE: Azimuth degrees are for text reference only (do not mark).

FIGURE 6-1

CALIBRATION CIRCLE FOR ANTENNA ARRAY

(SCHEMATIC OVERHEAD VIEW)

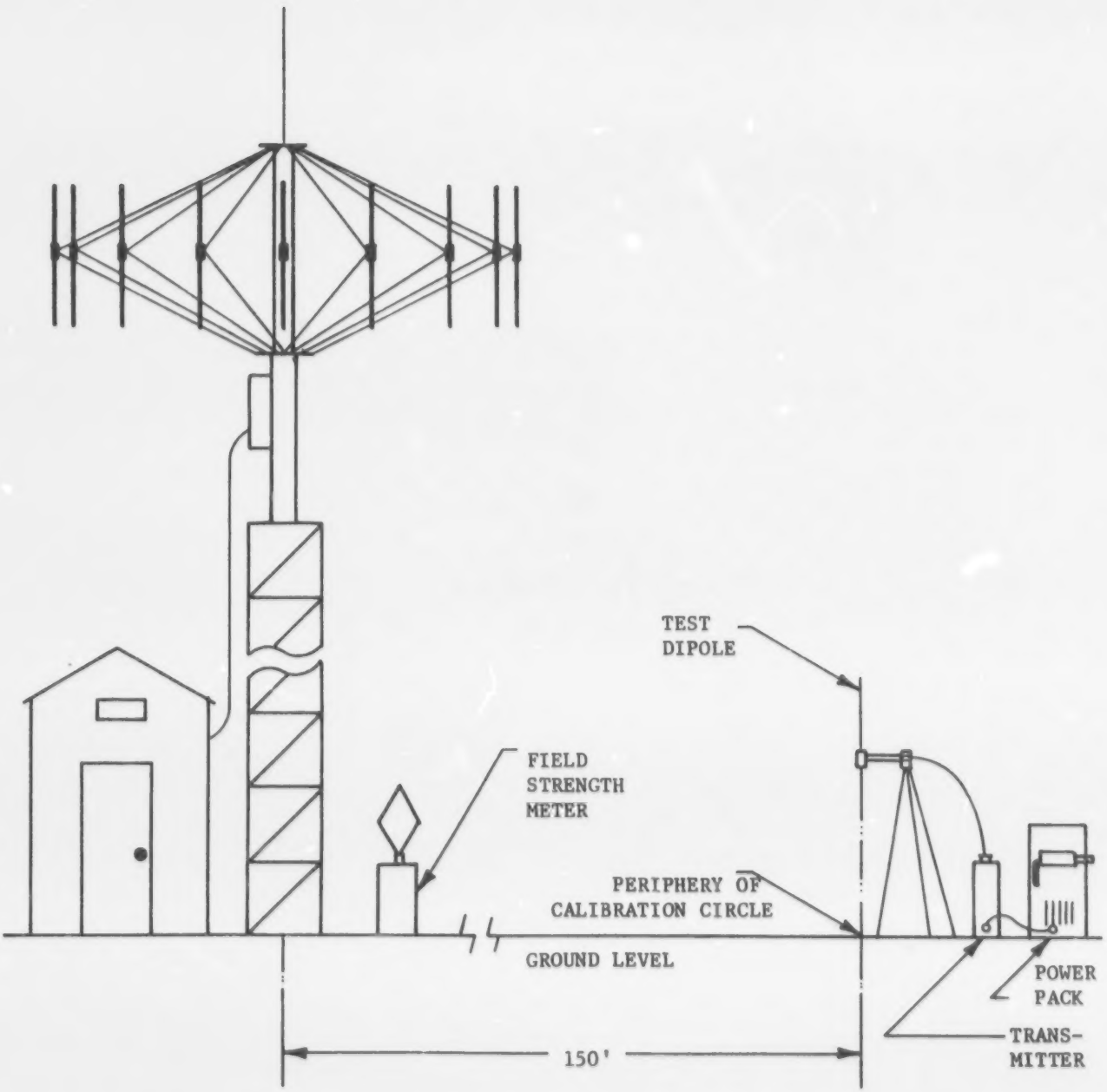


FIGURE 6-2

TEST SET-UP SCHEMATICAL VIEW

(GROUND LEVEL)

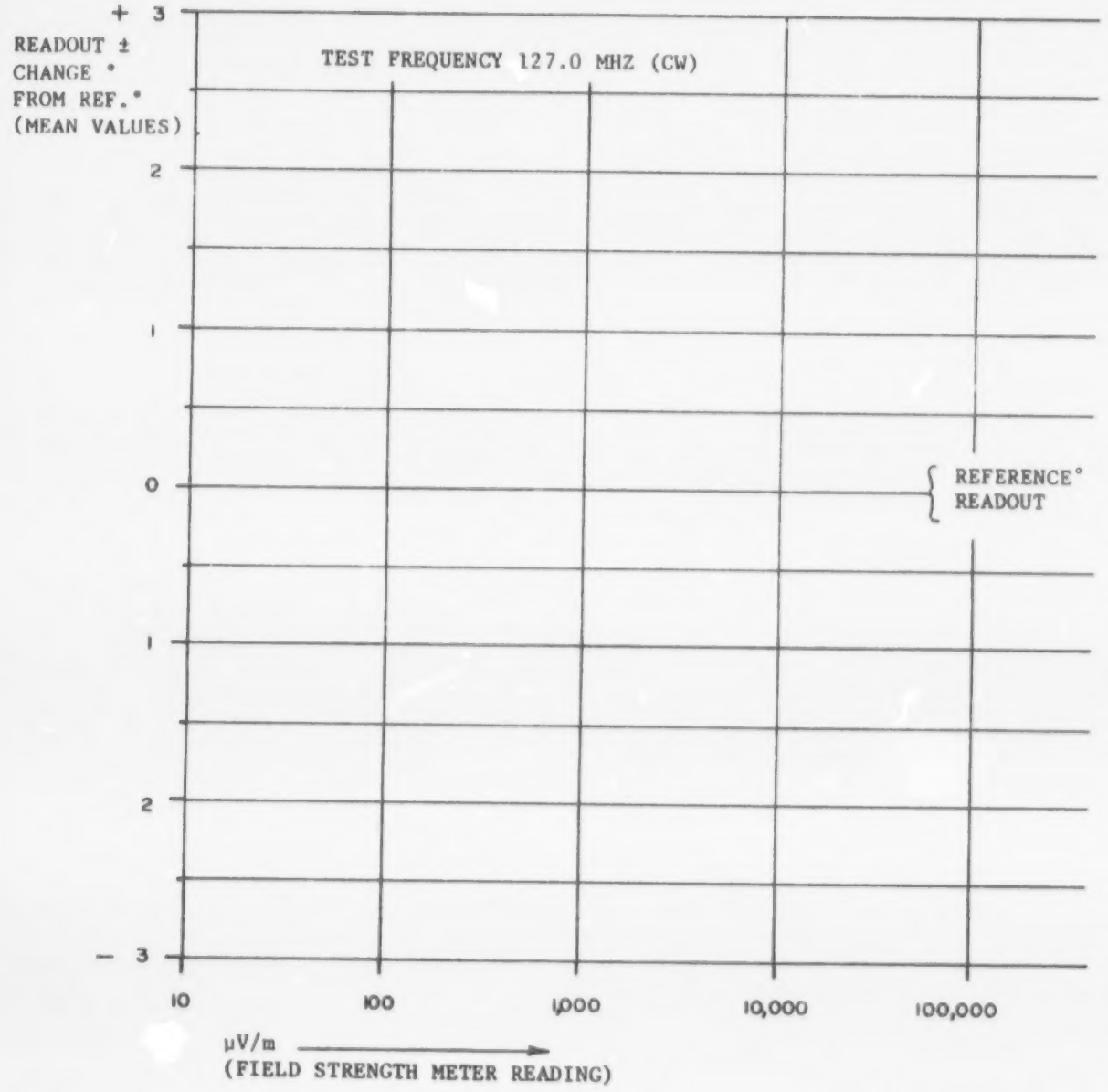


FIGURE 6-3

STRONG-SIGNAL EFFECT ON BEARING READOUT

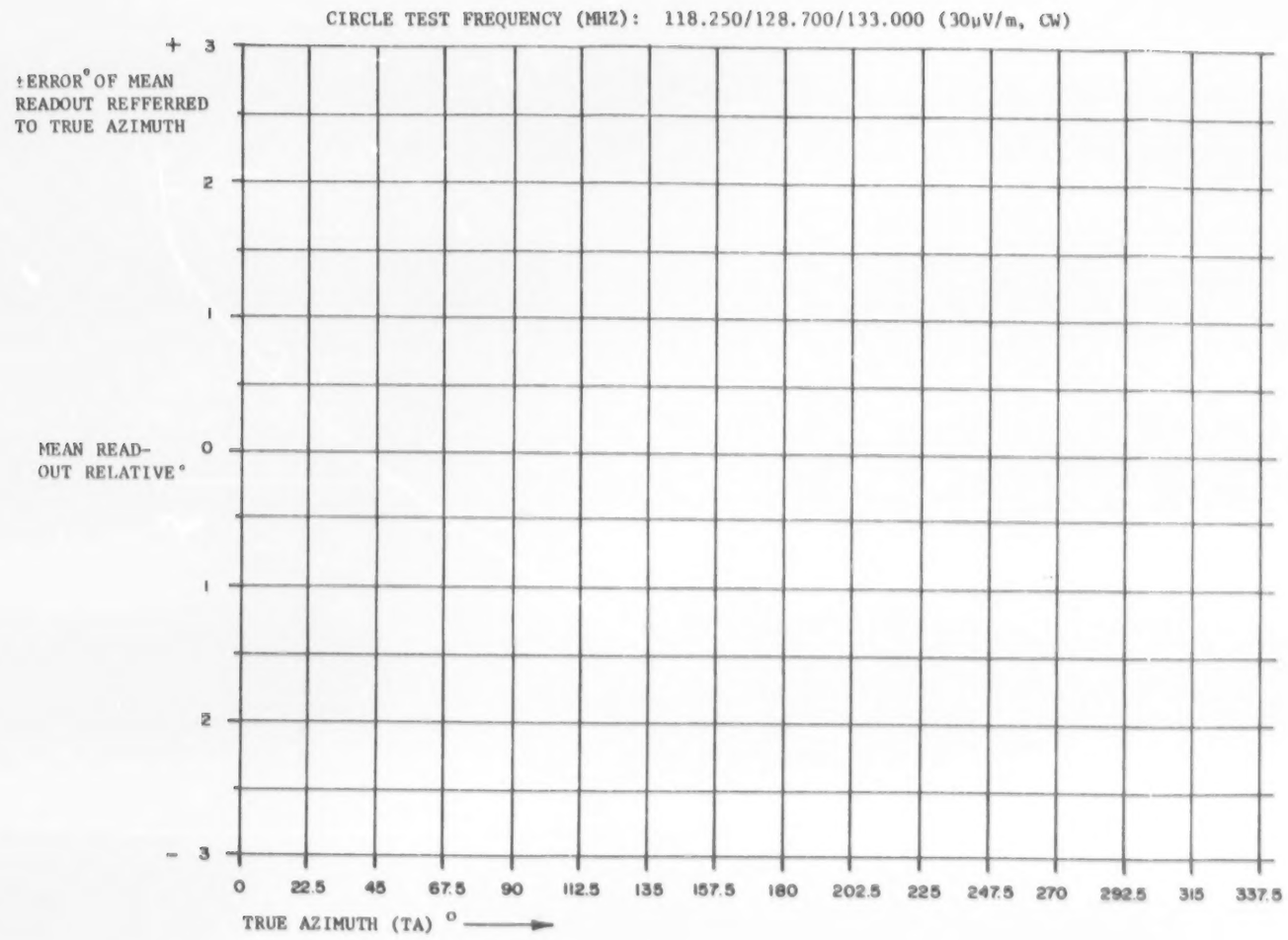


FIGURE 6-4

BEARING READOUT ERROR REFERRED TO TRUE AZIMUTH

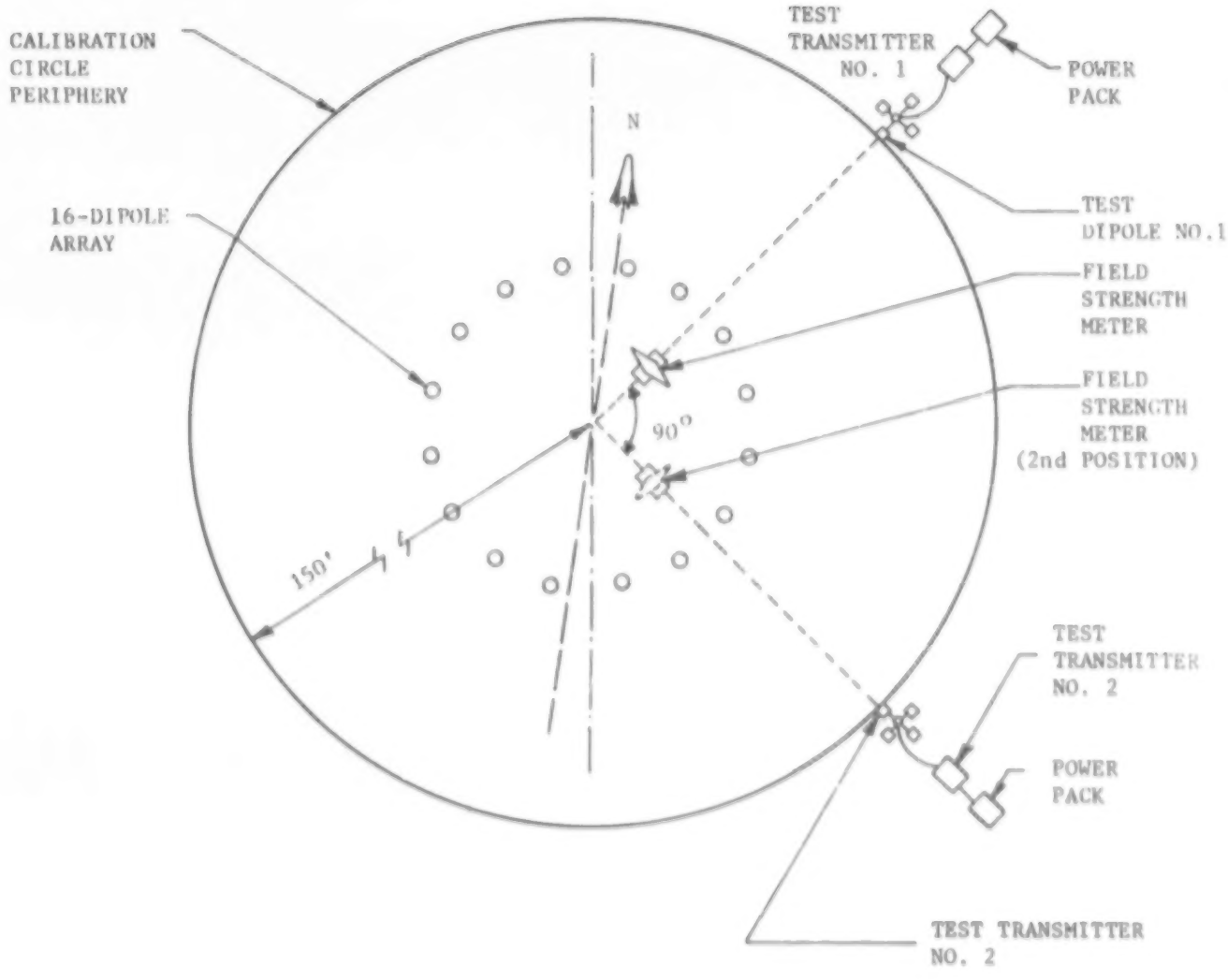


FIGURE 6-5

TEST SET-UP FOR TWO TRANSMITTERS

(OVERHEAD VIEW)